# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



**1. AGENCY USE ONLY** *(Leave blank)*

**2. REPORT DATE**
April 1996

**3. REPORT TYPE AND DATES COVERED**

**4. TITLE AND SUBTITLE**
Instrumentation Timing Systems

**5. FUNDING NUMBERS**

**6. AUTHOR(S)**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
Telecommunications and Timing Group
Range Commanders Council
White Sands Missile Range, NM 88002-5110

**8. PERFORMING ORGANIZATION REPORT NUMBER**
RCC Document 204-96

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
STEWS-RCC
Range Commanders Council
White Sands Missile Range, NM 88002-5110

**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
same as block 8

**11. SUPPLEMENTARY NOTES**
Replaces RCC Document 204-81    AD A109005

**12a. DISTRIBUTION/AVAILABILITY STATEMENT**
DISTRIBUTION A: APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

**12b. DISTRIBUTION CODE**

**13. ABSTRACT** *(Maximum 200 words)*

Describes timing systems and facilities available at various Range Commanders Council member and associate member ranges.



**14. SUBJECT TERMS**
timing, telecommunications

**15. NUMBER OF PAGES**
125

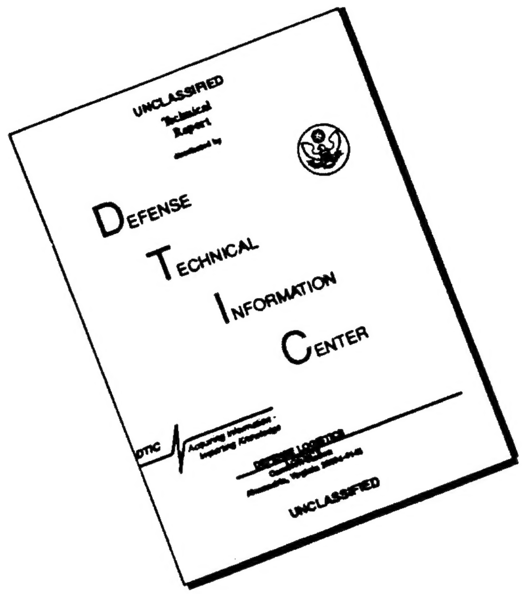
**16. PRICE CODE**

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| unclassified | unclassified | unclassified | none |

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

# DISCLAIMER NOTICE




**THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.**

## GENERAL INSTRUCTIONS FOR COMPLETING SF 298

The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to ***stay within the lines*** to meet ***optical scanning requirements***.

**Block 1.** Agency Use Only *(Leave blank)*.

**Block 2.** Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least the year.

**Block 3.** Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable, enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

**Block 4.** Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, add volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

**Block 5.** Funding Numbers. To include contract and grant numbers; may include program element number(s), project number(s), task number(s), and work unit number(s). Use the following labels:

| | | | |
|---|---|---|---|
| **C** | - Contract | **PR** | - Project |
| **G** | - Grant | **TA** | - Task |
| **PE** | - Program Element | **WU** | - Work Unit Accession No. |

**Block 6.** Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

**Block 7.** Performing Organization Name(s) and Address(es). Self-explanatory.

**Block 8.** Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

**Block 9.** Sponsoring/Monitoring Agency Name(s) and Address(es). Self-explanatory.

**Block 10.** Sponsoring/Monitoring Agency Report Number. *(If known)*

**Block 11.** Supplementary Notes. Enter information not included elsewhere such as: Prepared in cooperation with...; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

**Block 12a.** Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NOFORN, REL, ITAR).

- **DOD** - See DoDD 5230.24, "Distribution Statements on Technical Documents."
- **DOE** - See authorities.
- **NASA** - See Handbook NHB 2200.2.
- **NTIS** - Leave blank.

**Block 12b.** Distribution Code.

- **DOD** - Leave blank.
- **DOE** - Enter DOE distribution categories from the Standard Distribution for Unclassified Scientific and Technical Reports.
- **NASA** - Leave blank.
- **NTIS** - Leave blank.

**Block 13.** Abstract. Include a brief *(Maximum 200 words)* factual summary of the most significant information contained in the report.

**Block 14.** Subject Terms. Keywords or phrases identifying major subjects in the report.

**Block 15.** Number of Pages. Enter the total number of pages.

**Block 16.** Price Code. Enter appropriate price code *(NTIS only)*.

**Blocks 17. - 19.** Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

**Block 20.** Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (unlimited) or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.

Range
Commanders
Council

TELECOMMUNICATIONS
AND TIMING GROUP

DOCUMENT 204-96

# INSTRUMENTATION TIMING SYSTEMS

WHITE SANDS MISSILE RANGE
KWAJALEIN MISSILE RANGE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER

ATLANTIC FLEET WEAPONS TRAINING FACILITY
NAVAL AIR WARFARE CENTER WEAPONS DIVISION
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT
PACIFIC MISSILE RANGE FACILITY

30TH SPACE WING
45TH SPACE WING
AIR FORCE FLIGHT TEST CENTER
AIR FORCE DEVELOPMENT TEST CENTER
AIR WARFARE CENTER
ARNOLD ENGINEERING DEVELOPMENT CENTER

DISTRIBUTION A: APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION IS UNLIMITED

DOCUMENT 204-96

# INSTRUMENTATION TIMING SYSTEMS

APRIL 1996

Prepared by

TELECOMMUNICATIONS AND TIMING GROUP
RANGE COMMANDERS COUNCIL

Published by

Secretariat
Range Commanders Council
U.S. Army White Sands Missile Range,
New Mexico 88002-5110

# PREFACE

The first edition of document 204-81, Instrumentation Timing Systems, was published in November 1981. This new edition, like the old one, describes the timing systems and facilities available at the various Range Commanders Council member and associate member ranges. Some of the material presented in the previous edition has been deleted, because it does not specifically contribute to this limited intent.

Because the document is published in a loose-leaf format, revisions and additions may be issued at more frequent intervals. Member and associate member ranges are encouraged to submit any significant updating information as it becomes available. Send such information to

Secretariat
Range Commanders Council
STEWS-RCC
ATTN: Chairman, Telecommunications and Timing Group
White Sands Missile Range, New Mexico 88002-5110

# TABLE OF CONTENTS

## TABLE OF CONTENTS

**SECTION** | **PAGE**

SECTION 1

# AIR FORCE DEVELOPMENT TEST CENTER
# EGLIN AIR FORCE BASE
# RANGE TIMING SYSTEM

## 1.0 INTRODUCTION

The mission of Air Force Development Test Center (AFDTC), located at Eglin Air Force Base, Fort Walton Beach, Florida, is to develop and test all non-nuclear weapons for the Air Force.

## 2.0 CAPABILITIES

Timing Signals:

| | |
|---|---|
| Code Format: | IRIG A dc |
| | IRIG B Modulated and dc |
| Repetition Rates: | IRIG A = 10 pps |
| | IRIG B = 1 pps |
| Primary Frequencies: | IRIG A = 139.14 MHz |
| | IRIG B = 141.20 MHz |
| Other: | N/A |

Time Accuracy: Reference TRAK 8810B-41 Global Positioning System (GPS) station clock 100 ns or less with selective availability off, 200 to 300 ns with selective availability on.

Frequency Accuracy: Transmitter ± 200 Hz

Frequency Stability: Exciter Specs ± 500 Hz

Availability: 24 hours a day, 7 days a week if needed. Regular hours are from 0700 to 1500, Monday through Friday.

## 3.0 TIMING SYSTEM DESCRIPTION

The Central Timing Facility (CTF) provides triple redundant time code generators with error detecting circuits. In addition, the CTF has dual FM transmitters for transmitting Interrange Instrumentation Group (IRIG) time formats which provide an accurate time code for data correlation, theodolite camera control, and rate operation.

Model 8362 Time Code Generator and GPS model 8810 Station Clock/Time Code Generator are used to generate IRIG time code. Model 8810 is the primary generator. For synchronization, GPS models 9390 and 3650 serve as backups to model 8810. Interface equipment consists of modulation terminal units, control function relay chassis, control function generator, systems comparator, line driver, control function generator interface panel, ac input panel, time reference selector panel, and test equipment. Four 500-watt transmitters are used for the transmission of time codes. Transmission and reception of time codes are through an antenna system (10 antennas) located on buildings 129 and 130. Figure 1-1 provides a block diagram of the range timing system.

The Contraves Range Time Synchronization System (CONRATS) Mission Control has 17 theodolite sites which control 26 camera sites. There are 15 data collection sites consisting of CCTV Video, FCA VAN, Telemetry (Penthouse, TM VAN, Eagle Ops, and MSIP), C80, C74, C74L, C3, C1, C64, A22, A24, and the Climatic Laboratory.

## 4.0 NEAR-TERM PLANNED UPGRADES

The range will continue to replace LORAN synchronized time code generators with GPS time code generators.

## 5.0 LONG-TERM PLANNED UPGRADES

All high speed cameras will use IRIG G instead of A code format.

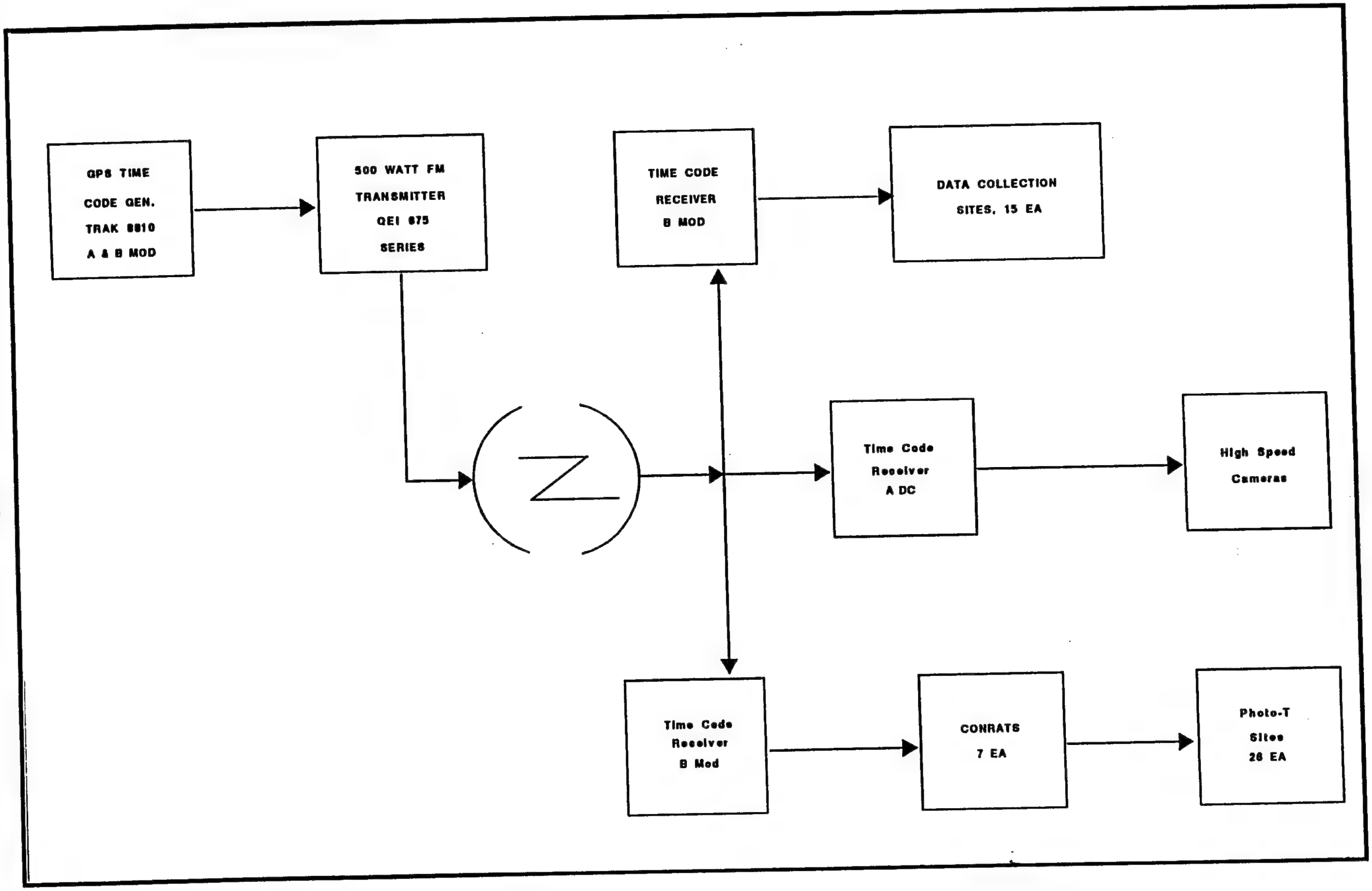



Figure 1-1. AFDTC range timing system.

SECTION 2

# HOLLOMAN AIR FORCE BASE
# 46TH TEST GROUP
# 846TH TEST SQUADRON/TECHNICAL DATA CENTER/
# TIMER/PROGRAMMER ELEMENT

## 1.0 INTRODUCTION

The Timer/Programmer System provides precise real time signals for mission control and data collection capabilities. Through an extensive landline cabling system, timing signals are communicated to any location along a 50,788-foot (15,480-meter) test track including two major laboratories, five permanent blockhouses, a rocket engine test stand, three mobile launch sites, and various countdown clocks.

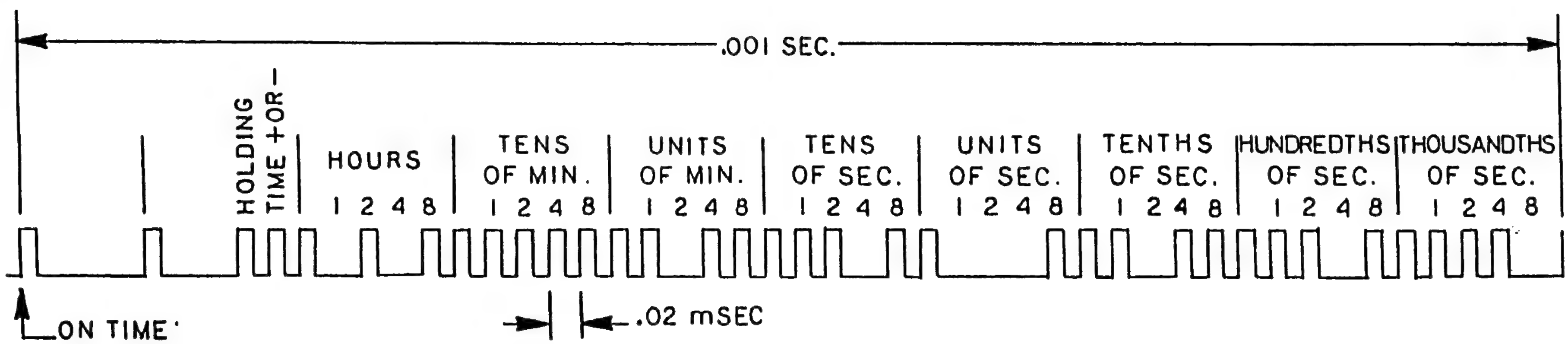
Each blockhouse and mobile launch facility has a firing panel, a countdown clock, and additional lines for other timing requirements. Each firing panel is equipped for both programmed and manual firing capabilities. The countdown sequence can be programmed to allow mission hold and stop capabilities from the launch facility or control center.

Timing is provided to 137 connections at pads, terminals, and towers in addition to 3 terminal vaults used in turning on and off instrumentation equipment. This equipment includes camera controllers, power supplies, and telemetry packages. This timing is also valuable as a reference tool for time tagging and calculating high speed velocity missions (currently striving for Mach 10). Timing is supplied for recording all magnetic data tapes, camera film, and oscillographs.

## 2.0 CAPABILITIES

Real time IRIG timing formats (modulated and dc levels), general time (see figure 2-1), programmable frequencies, and programmable dc levels are sent through 120 balanced and 30 unbalanced line drivers. Line driver outputs are individually controllable through programming.

The system accuracy is obtained by automatically synchronizing to Coordinated Universal Time (UTC) via GPS received data through two time code generators. Each time code generator has its own Rubidium Standard as its frequency source. The alarm transfer unit monitors the outputs of both time code generators. If either unit fails, it is automatically switched to the backup unit upon detection. The long term accuracy of the Rubidium Standard is enhanced by the frequency correlating its outputs to the Cesium Beam Frequency Standard derived GPS data. This system is also employs an uninterruptable power system for emergency support up to 18 hours.




1. TIME SHOWN IS +5 HRS. 02 MIN. 47 SEC. 248 mSEC., COUNTDOWN NOT HOLDING. THIS TIME REFERS TO THE INSTANT OF TIME NOTED ON THE DRAWING AS "ON TIME." TIME IS DENOTED IN BINARY CODED DECIMAL BY THE OMISSION OF THE APPROPRIATE PULSES. COUNTDOWN HOLDING IS DENOTED BY THE OMISSION OF THE HOLDING PULSE. MINUS (–) TIME IS DENOTED BY THE OMISSION OF THE TIME (+ OR –) PULSE.
2. THE SYNC WORD IS 10000100.
3. TIMING IS SHOWN FOR A CLOCK RATE OF 50 KHz. ALL TIMING CHANGES ARE IN PROPORTION TO A CLOCK RATE INPUT CHANGE.
4. PULSES AND SPACES ARE OF EQUAL LENGTH.

Figure 2-1. General time code format.

The outputs are IRIG A, IRIG B, IRIG G, and IRIG H at various voltage levels. The IRIG outputs are available either modulated or DC level shifts. Other signals available are dc levels 1, 10, 100, 1000, 10,000, and 100,000 pps.

## 3.0 ACCURACY

Time accuracy is 100 microseconds (0.0001) with a resolution of 1 microsecond (0.000001). The frequency accuracy and stability are a factor of the Rubidium Standard and are synchronized with GPS.

## 4.0 NEAR-TERM PLANNED UPGRADES

Fiber optic integration capabilities are currently being reviewed. A modification to add IRIG E is being considered to further enhance capabilities.

## 5.0 LONG-TERM PLANNED UPGRADES

A radio frequency (RF) timing system to replace the current landline cabling system is planned as well as the development of a trackside differential GPS setup that could be used with sled borne instrumentation.

# SECTION 3

# AIR FORCE FLIGHT TEST CENTER
# EDWARDS AIR FORCE BASE, CALIFORNIA
# INSTRUMENTATION TIMING SYSTEM

## 1.0 INTRODUCTION

The Edwards Air Force Base Master Timing System provides the necessary timing signals to various Air Force Flight Test Center (AFFTC) range users. This system provides center-wide coverage for Edwards Air Force Base and Phillips Laboratory (PL). The Master Timing System consists of (1) a Master Timing Station (MATS) where a wide variety of timing signals are generated, (2) a redundant point to point RF and landline link between the MATS and the remote very high frequency (VHF) transmitter, (3) dual VHF transmitters, (4) timing terminal units located at strategic and scattered timing user sites, and (5) aircraft time code generators with associated ground station support units.

The MATS signal generators and the VHF timing transmission incorporate standby power sources, so automatic switch over to emergency power is accomplished within milliseconds (msec) following the loss of main ac power. Protection against transient power fluctuations such as switching over to standby power sources or short term (0.05 second or less) power dropouts is provided by standby batteries at the MATS.

## 2.0 MASTER TIMING STATION (MATS) DESCRIPTION

Timing signals are derived from three parallel signal generators. Two of the generators (the primary and the secondary) provide the full complement of timing signals. The third generator (the comparator) duplicates only a specific portion, resulting in the three signal source configuration that accomplishes both time and bit error detection. The primary generator is normally the generator on line. When bit errors for any of the on-time code signals occur within a specific number of successive time frames, or when the signal output voltage drops below 75 percent of normal, the secondary generator is selected as the primary signal source. When the automatic switchover to the secondary generator occurs, it is initiated on the next on-time second, thereby, minimizing switchover disturbance. The MATS provides 4 different serial time codes, 7 cinetheodolite control signals, and 15 different pulse rate outputs. A block diagram of the MATS is shown in figure 3-1, followed by a description of the signals discussed previously.

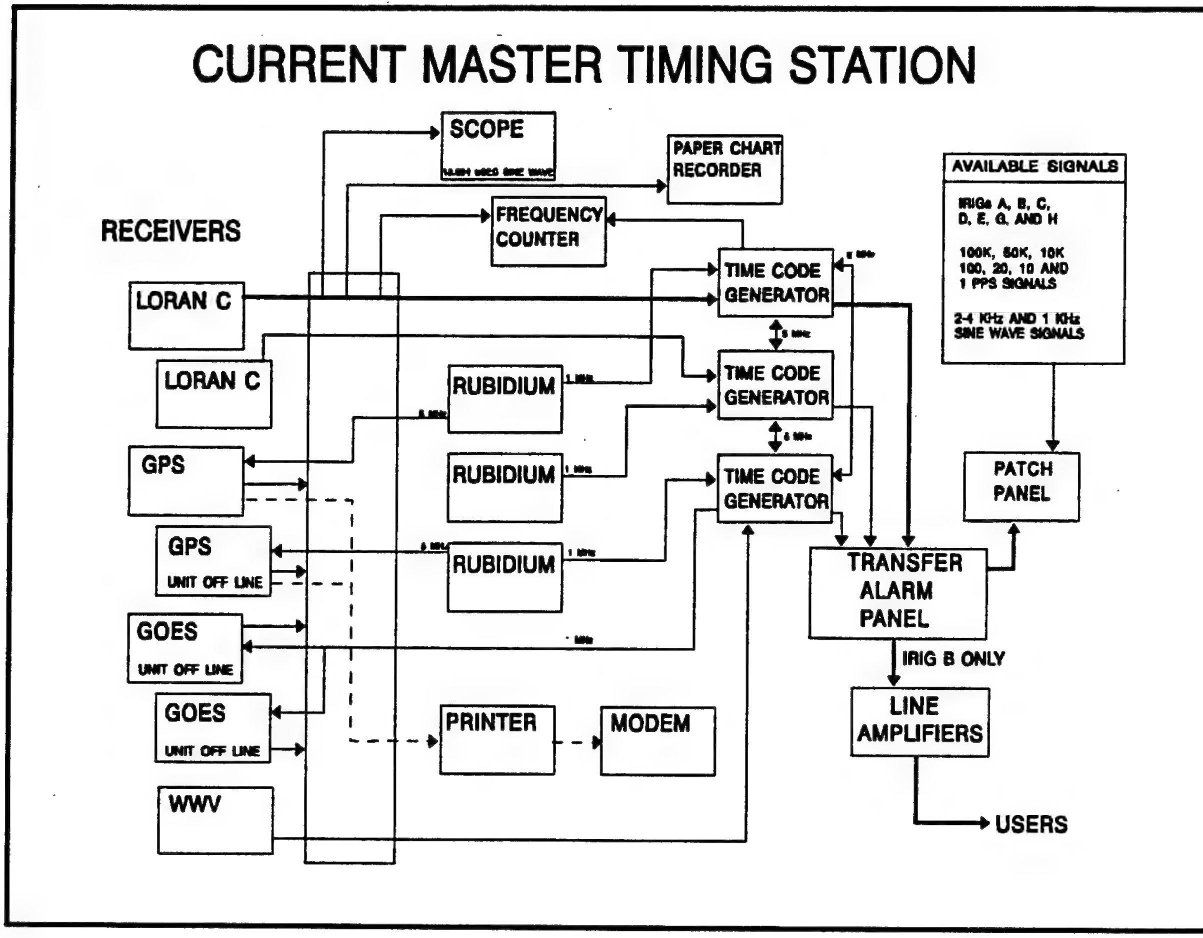



Figure 3-1. Current master timing station.

IRIG A: binary coded decimal (BCD) time of year plus straight-binary (SB) time-of-day, provided as a dc level shift and amplitude modulated 10 kHz carrier.

IRIG B: BCD time-of-year plus SB time-of-day, provided as a dc level shift and amplitude modulated 1 kHz carrier.

IRIG C: provided as three separate signals: one signal as a dc level shift, the second signal as an amplitude modulated 1 kHz carrier, and the third signal as an amplitude modulated 100 Hz carrier.

IRIG D: dc level shift and amplitude modulated 100 Hz carrier.

IRIG E: BCD time-of-year plus SB time-of-day, provided as three separate signals: one signal as a dc level shift, the second signal as an amplitude modulated 1 kHz carrier, and the third as an amplitude modulated 100 Hz carriers.

Format F: one pulse per 5 seconds basic element rate, 5 minute time frame, 21 bit BCD time-of-year information. Code uses same format as IRIG D except for addition of 5 bit BCD minutes. Provided as three separate signals: one signal as a dc level shift, the second signal as an amplitude modulated 1 kHz carrier, and a third signal as an amplitude modulated 100 Hz carrier.

1 KPPS Time Code (Used for Askania Cinetheodolite, not takeoff and landing (TOL). The 1 kpps (kilopulses per second) time code format consists of 20 pulse intervals (index counts) which are uniform periods of time. One complete time frame is 20 msec in duration. Thus, the time code is produced at a 1000 pps (pulses per second) rate. An element of the time code is generated each pulse interval. Specific elements are designated as reference marker, code digits, time-of-day code word, and index markers. These elements are described below.

Reference Marker. The reference marker is 0.8 msec in duration. "On time" occurs at the leading edge of the marker. The leading edge or the reference marker defines the beginning of each time frame.

Code Digits. The code digits are the binary 1s and 0s that make up the time-of-day code word. The 1s are 0.5 msec wide and the 0s are 0.2 msec wide.

Time-of-Day Code Word. Time-of-day is encoded in three subcode words: seconds, minutes, and hours. Each subcode word is weighted in straight binary fashion. The time-of-day code word begins at index count 1.

Index Markers. The index markers are 0.2 msec in duration and occur at index counts 18 and 19.

Cinetheodolite Control (Contraves). This code consists of two sets of two pulses for two operational contraves configurations. One has a 10 msec pulse width, and the second has a 1 msec pulse width. The leading edge of the 10 msec pulse occurs 50 msec prior to the leading edge of the 1 msec pulse whose leading edge occurs on time. This time relationship is maintained regardless of code repetition rate. The pulse code is provided as four separate channels with code repetition rates of 1, 2, 4, 5, and 10 pps, which are switch selectable on the individual channels. This control code is inserted on to the modulated IRIG B prior to leaving the MATS.

Pulse Rate Outputs. The station provides 15 separate positive going pulse outputs of 1, 2, 4, 5, 10, 20, 30, 50, 60, 100, 500, 1000, 10,000, 100,000, and 1,000,000 pps. (Signals of 100 pps and above are transistor/true logic (TTL.))

## 3.0 DISTRIBUTION

Timing signals (modulated IRIG B) are distributed to users by two methods: hard wire or RF transmission. For hard wire distribution, the individual signals, as required by the timing user, are patched from the primary time code generator outputs through individual line driver amplifiers to various transmission lines terminated at the station. A variety of individual plug-in line driver amplifiers, which meet specific signal characteristics, line level, and load requirements are used to output signals to the users. A time division multiplexed (TDM) microwave is used for RF distribution. The TDM microwave code uses a 1 msec time frame and a 50 kHz bit rate serial pulse train which allows programming of up to 43 timing channels. Seven of the channel slots within the time frame are used for frame synchronization. These channels are microwaved to the site of the remote VHF transmitter where the timing signals are decoded back into analog. The modulated IRIG B signal is then transmitted to various users at other remote sites via the VHF transmitter.

Terminal Equipment. At each timing user site, there is a timing terminal unit installed which accepts the TDM code from a VHF receiver and provides parallel decoded signals at the output. A patching arrangement is also provided, so that available timing signals may be connected through line driver amplifiers directly to data acquisition equipment or transmission lines for further distribution. The same types of line driver amplifiers, as used in the master timing station, are used in each terminal unit. A limited number of VHF receivers, which provide an amplitude modulated IRIG B signal, can be provided to customers when requested.

Aircraft Timing. Aircraft timing needs are met by a small, lightweight time code generator which furnishes signals for time correlation of instrumentation data recorded aboard test aircraft. Each generator includes a remote control box and a maximum of three remote time-of-day display units. Time-of-year synchronization, monitoring, and storage functions are provided by the ground station support unit (GSSU). The GSSU accepts an IRIG B signal, disciplines the internal oscillator to the input, and synchronizes the aircraft time code generator to range time. Each time code generator has its own internal battery for continued operation during temporary loss of aircraft power, aircraft ground power, or during transport from the GSSU to the aircraft. Under these conditions, generator operation is confined to maintaining time-of-year count only. Battery operation is limited to a maximum of 45 minutes. The time code generator output signals are described as IRIG B (both dc level shift and amplitude modulated 1 kHz carrier time-of-year in BCD only) and IRIG E (both dc level shift and amplitude modulated 100 Hz carrier) 1 kpps pulse train; 1 pps pulse train; 1 kHz sine wave; and 5 pps, 1 pps, and 1 pp/10 seconds for driving an external relay circuit.

System Synchronization. Real time synchronization of the master station, in respect to LORAN C and GPS transmissions, is maintained within ±2 microseconds

(worst case). Range time is referenced to Coordinated Universal Time (UTC). The 50 microsecond error band is based on uncertainty of propagation delay correction and expected propagation delay variations as a function of time. Frequency comparisons of the two station Rubidium Standard are made with respect to VHF transmissions and, typically, standards are maintained within 1 part in $10^{12}$.

Rocket Propulsion Laboratory (RPL) Timing Distribution System. This distribution system furnishes time information for internal correlation between oscillograph, magnetic tape, and camera recorders throughout the RPL instrumentation complex. Time codes generated by the center timing system are available for distribution to the rocket site complex via hard wire.

## 4.0 NEAR AND LONG TERM TIMING UPGRADES

The Air Force Flight Test Center is in the process of upgrading its MATS at Edwards Air Force Base. The upgrade started in April 1994 and is scheduled to be completed in December 1995. In concert with the MATS upgrade, several instrumentation sites will receive on-site GPS timing receivers to generate local timing signals. This process was started in April 1994 and is scheduled to be completed in December 1997. A total of 27 remote instrumentation sites are expected to be upgraded. A description of the program and its goals are provided next.

## 5.0 SYSTEM OVERVIEW

The MATS upgrade is intended to replace the existing Master Timing Station in the Ridley Mission Control Center (RMCC) located at Edwards Air Force Base, California. The MATS will provide a stable frequency reference to all digital data communication systems within the RMCC, and those identified elsewhere on the Edwards range. The MATS will also provide a time reference to all systems currently supported, and those identified to be supported in the future. The time reference will be traceable to UTC to within 100 nanoseconds (nsec). The MATS will output IRIG B and G as the standard codes and support all other codes as required.

Part of the MATS upgrade will be to install GPS timing receivers and required interface equipment at remote sites, allowing them to syntonize with the RMCC. Using a stable GPS time and frequency reference, without the delays and noise inherent in the current system, will provide a more accurate and reliable signal source to these sites. As part of the remote site installations, it is a goal to have the VHF timing transmitter decommissioned and removed.

The new Master Timing Station will be composed of four functional subsystems: reference, distribution, control/monitor, and remote sites.

Reference Subsystem (RSS). The RSS will synchronize itself to a GPS reference using an atomic reference for measurements and will provide stable frequencies and time codes to the distribution subsystem. This subsystem will also provide alarm and monitoring information to the control/monitor subsystem.

Distribution Subsystem (DSS). The DSS will accept the RSS reference frequencies and time codes and distribute them to the range systems that require reference inputs and time codes.

Control/Monitor Subsystem (CMS). The CMS will be the only operator interface to the MATS. It will provide alarm and control interaction. The CMS will be composed of two separate personal computers (PCs). One is to be colocated with the MATS, primarily for control of the MATS and the acquisition of data (control PC). The second (monitor PC), which can be located up to 1000 feet away from the MATS, is to be used for monitoring MATS and displaying system data.

Remote Sites Subsystem (RMS). The RMS will be available for installation at any remote site to provide a frequency and time code reference to the equipment at the remote sites. The use of the RMS eliminates all line delays inherent in current communications links and will provide better time correlation because of improved signal quality. These RMSs will also provide a discrete alarm status signal to the CMS.

## SECTION 4

## AIR WARFARE CENTER
## 99TH RANGE SUPPORT SQUADRON
## NELLIS AIR FORCE BASE, NV

### 1.0 INTRODUCTION

The 99th Range Support Squadron provides timing to threats, RDIS, RFCC, RFMDS, and TSPI mission at Point Bravo.

### 2.0 CAPABILITIES

Timing Signals:

| | | |
|---|---|---|
| Code Format: | IRIG B | |
| Repetition rates: | N/A | |
| Primary frequencies: | | |
| | 138.125 MHz | Cedar Peak |
| | 138.12 MHz | Point Bravo |
| | 138.5 MHz | Point Bravo |
| Other: | N/A | |

Time accuracy: 0.5 microseconds

Frequency accuracy: $\pm 1 \times 10^{-11}$

Frequency stability:
$10^{-3}$ sec = $8.2 \times 10^{-10}$
$10^{4}$ sec = $8 \times 10^{-13}$

### 3.0 TIMING SYSTEM DESCRIPTION

The Master Timing Center (MTC) in building 200 is disciplined by a Cesium Beam Standard. Timing accuracy is verified by LORAN and GPS. The Secondary Timing Center accuracy is determined by a phase lock to LORAN. Timing accuracy is by LORAN, portable clock, and GPS. Figures 4-1, 4-2, 4-3, and 4-4 show the Master Timing Center's block diagram, buffer outputs, rack layout, and single line diagram. Figures 4-5, 4-6, and 4-7 reveal the Secondary Timing Center's block diagram, buffer outputs, and rack layout.

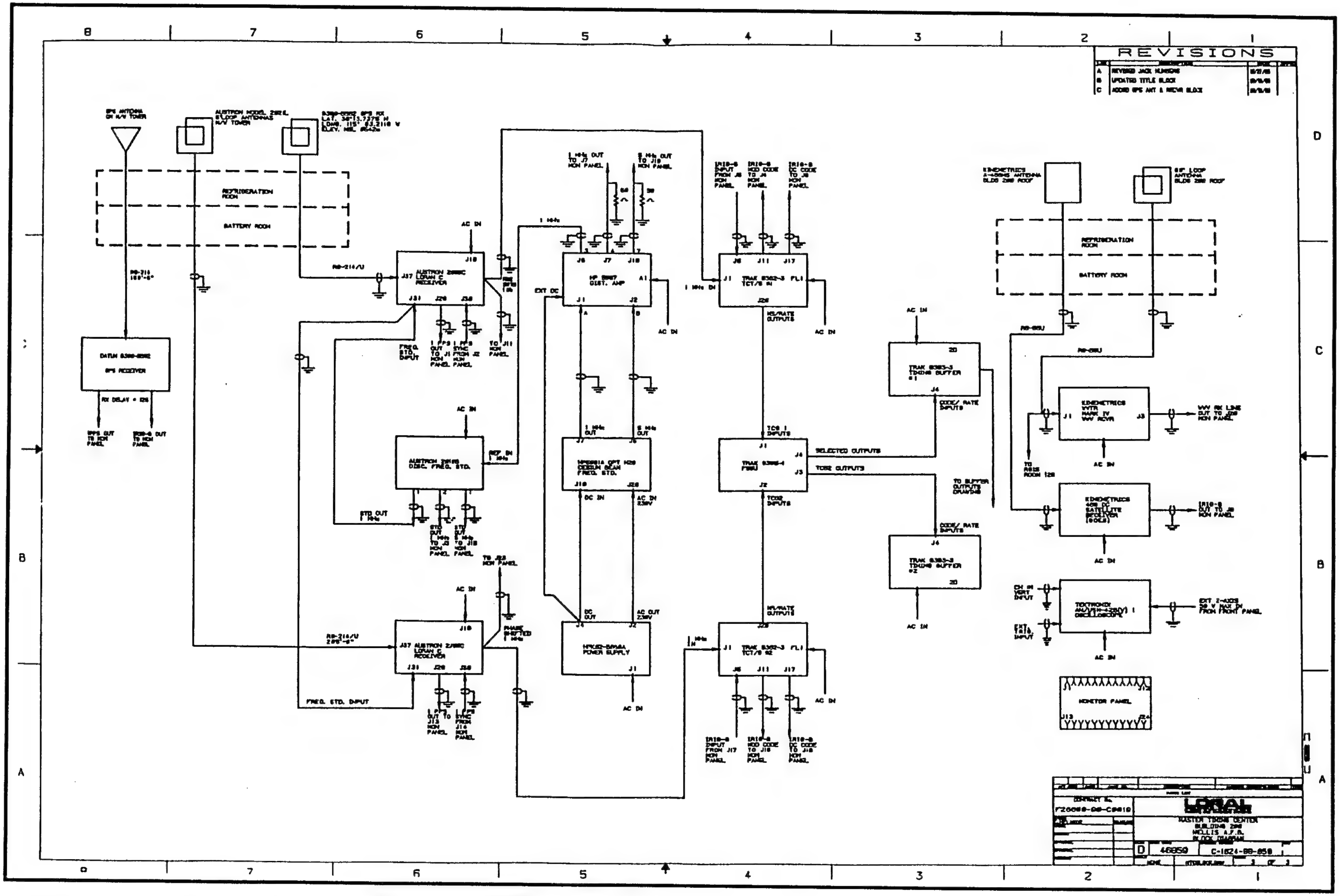



Figure 4-1. Master Timing Center block diagram.

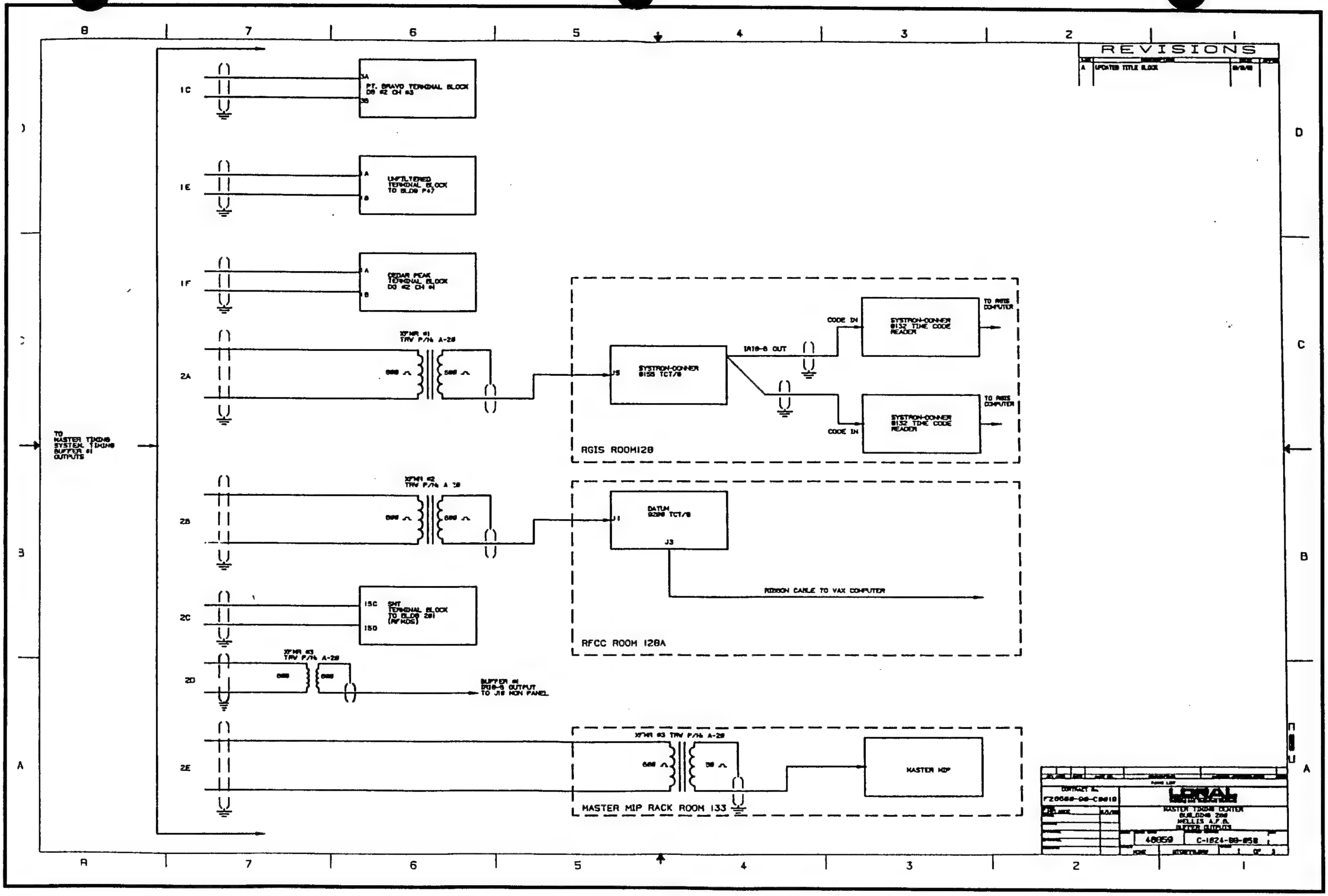



Figure 4-2. Master Timing Center buffer outputs.

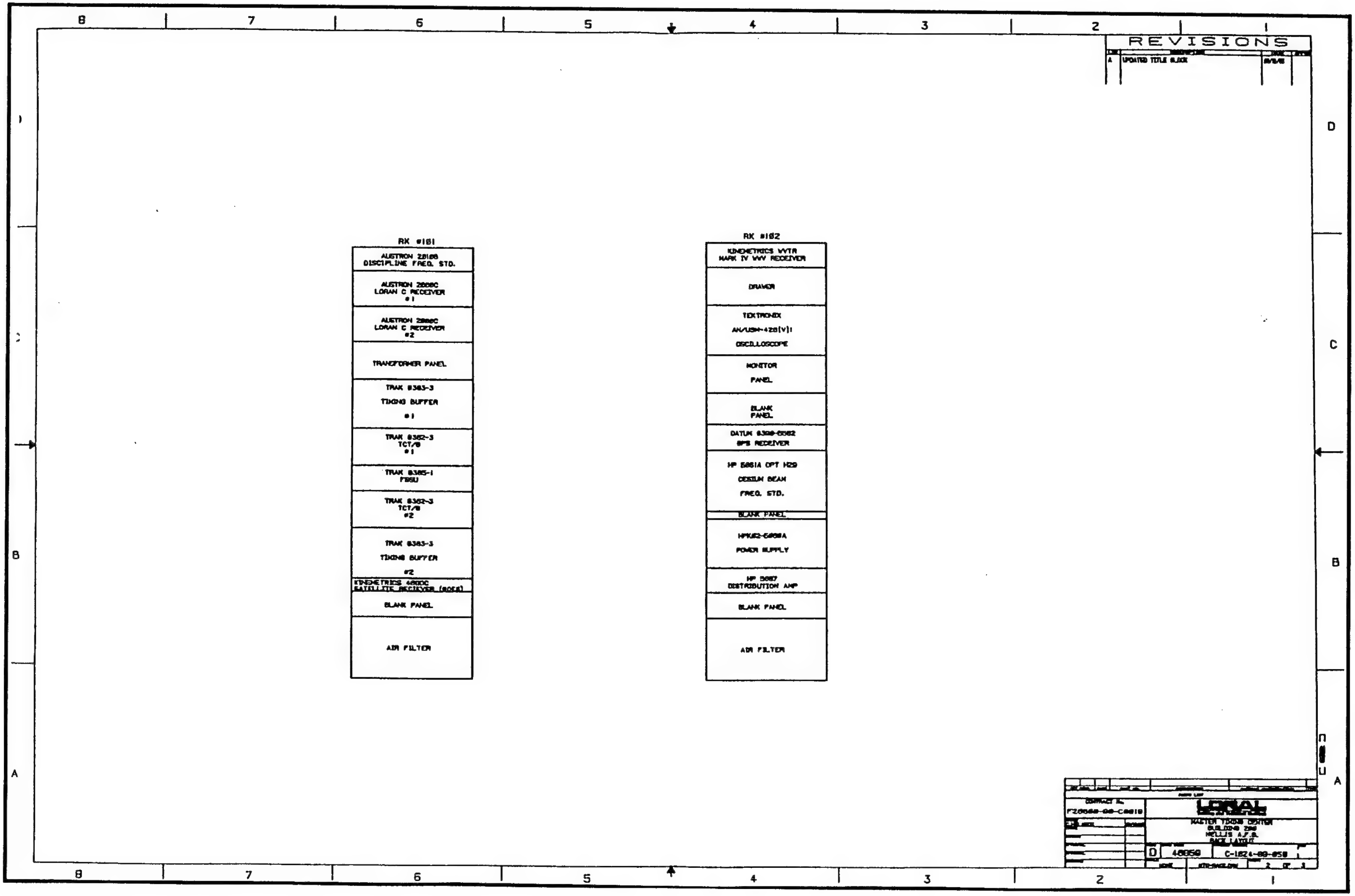



Figure 4-3. Master Timing Center rack layout.

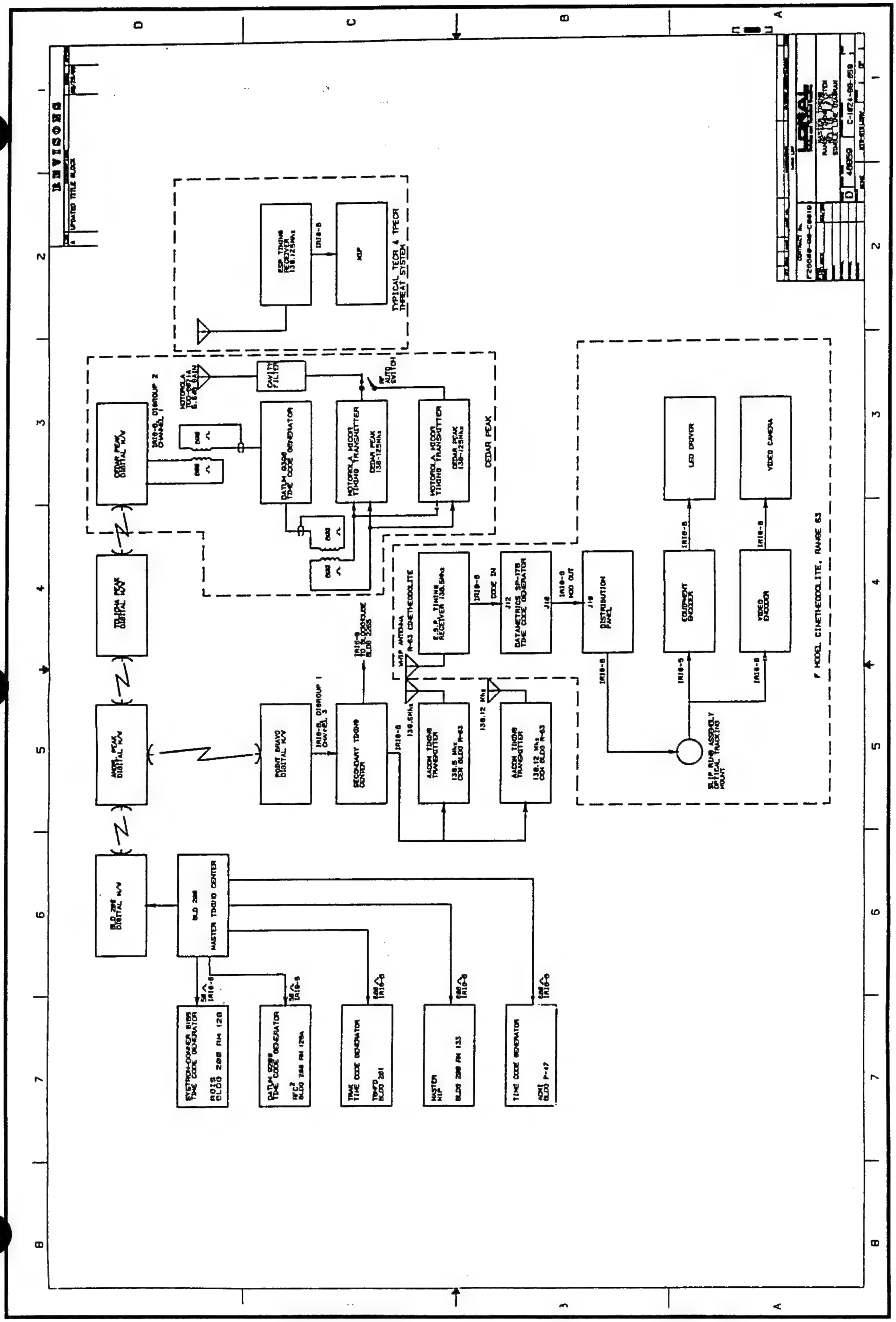


Figure 4-4. Master Timing Center single line diagram.

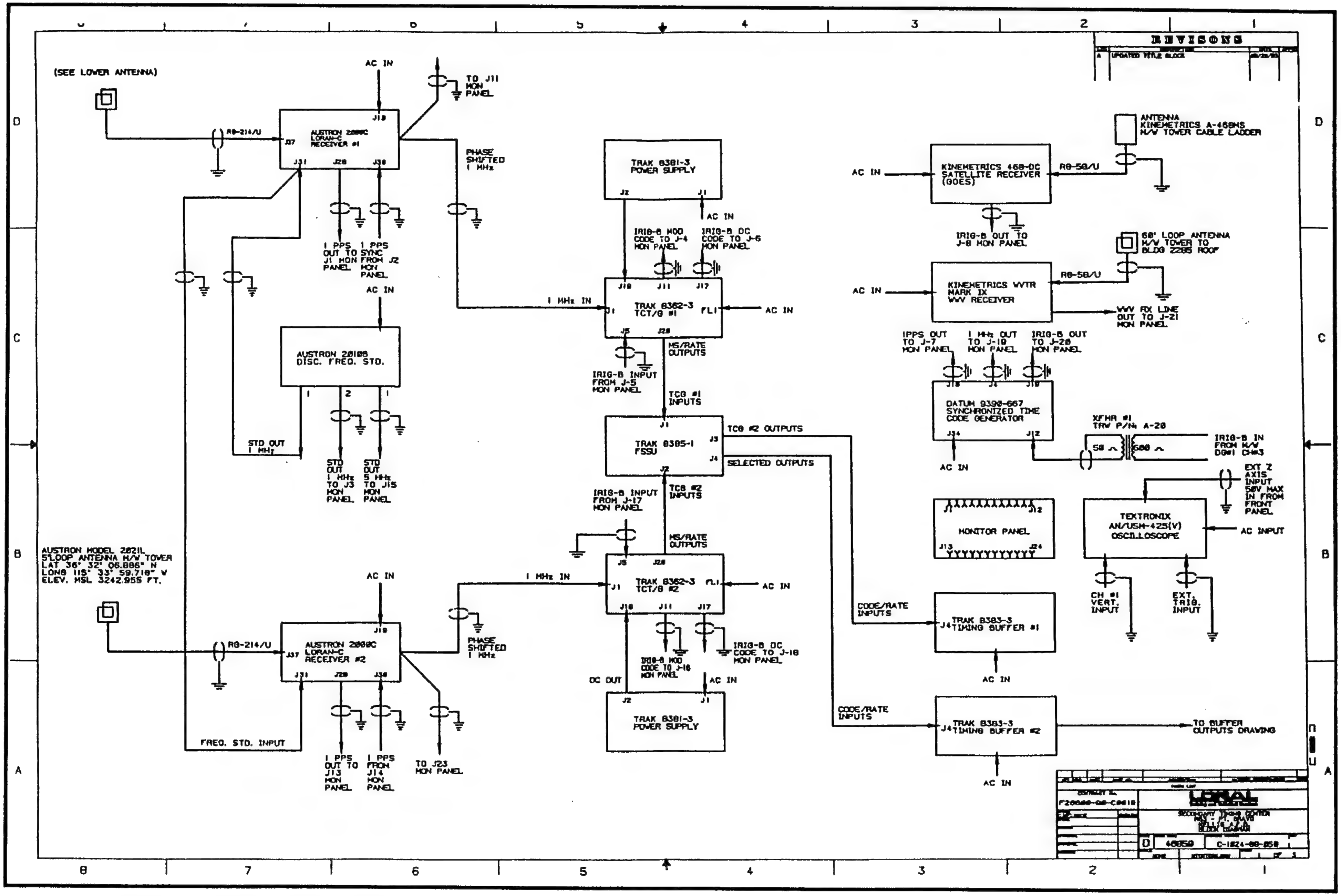



Figure 4-5. Secondary Timing Center block diagram.

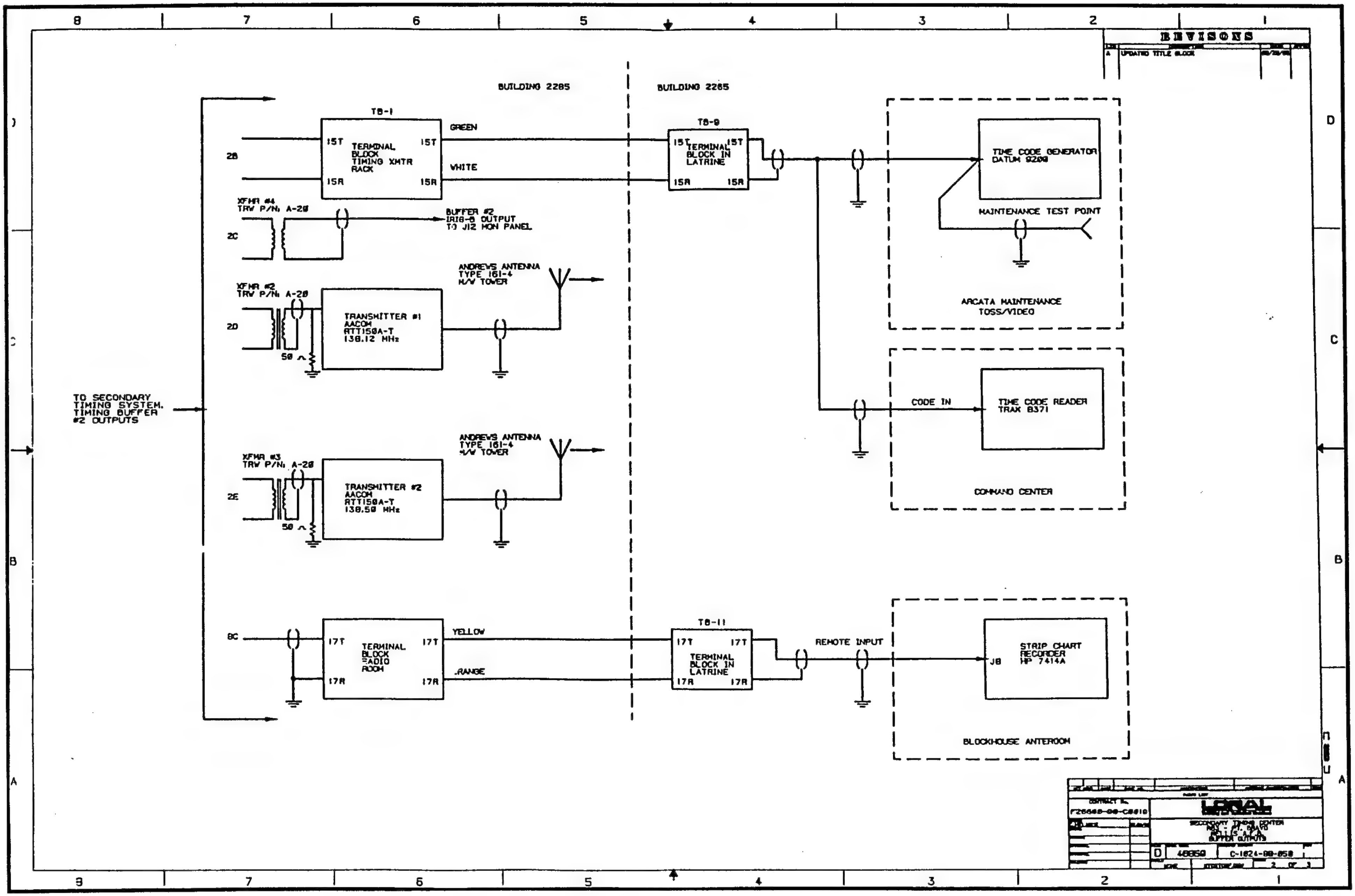



Figure 4-6. Secondary Timing Center buffer outputs.

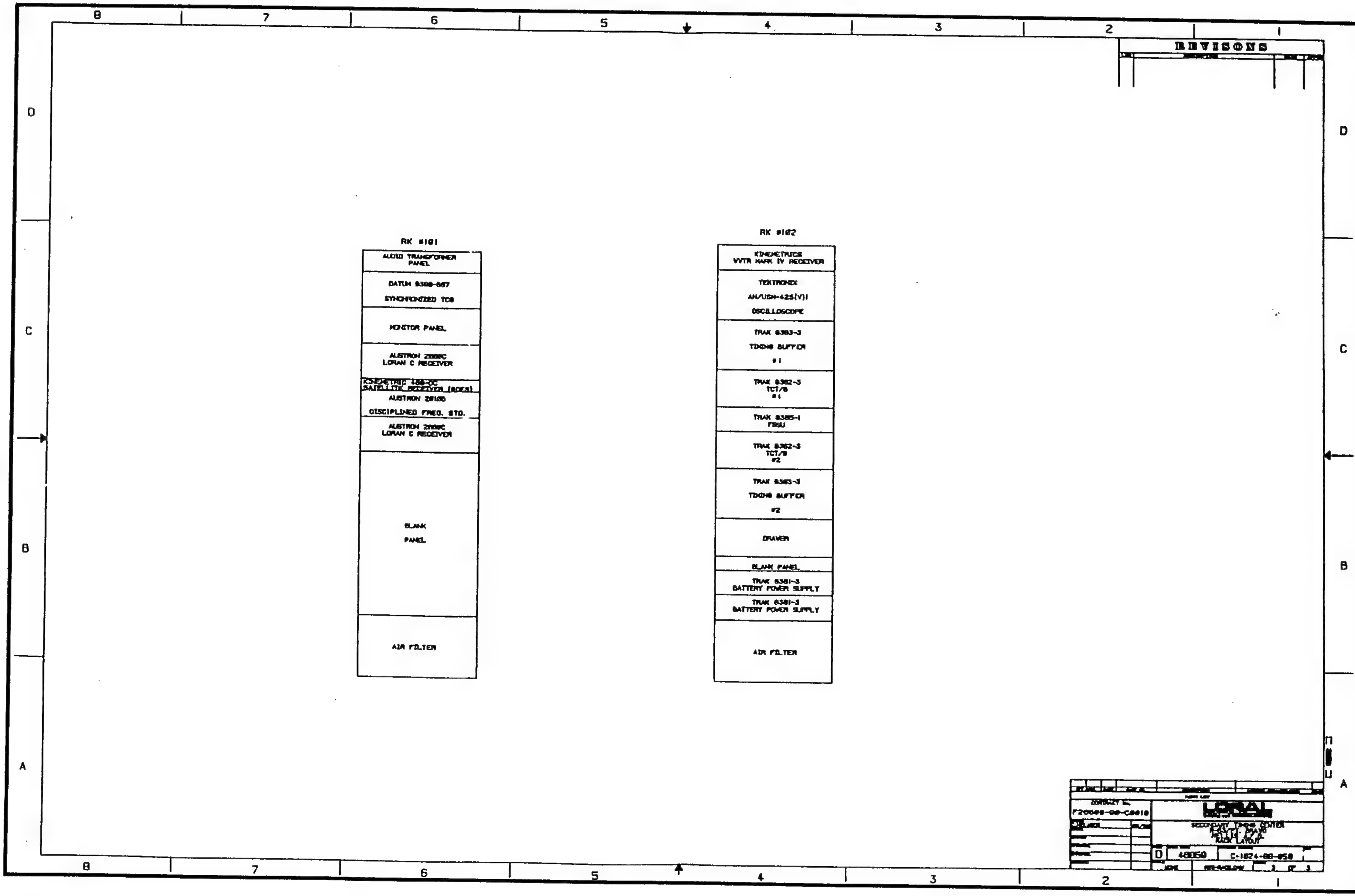



Figure 4-7. Secondary Timing Center rack layout.

## 4.0 NEAR-TERM PLANNED UPGRADES

Near-term plans include eliminating the Secondary Timing Center. Requirements can be met by a Datum 9390 slaved to the MTC.

## 5.0 LONG-TERM PLANNED UPGRADES

Long-term plans consist of replacing the MTC with two GPS receivers, switching unit, and buffer amp, because they will be more accurate than in the present system and maintenance man-hours will be reduced. This change should take place when the Cesium Beam Standard fails. The standard should completely fail within the next 1 to 3 years.

SECTION 5

# ATLANTIC FLEET WEAPONS TRAINING FACILITY

## 1.0 INTRODUCTION

The Atlantic Fleet Weapons Training Facility (AFWTF) mission is to operate, maintain, and develop weapons training facilities and services in direct support of the training of fleet forces and other activities and for the development, test, and evaluation, on a reimbursable basis, of weapons systems. The AFWTF consists of four major ranges: Outer Range (North and South), Inner Range, Underwater Range, and Electronic Warfare (EW) Range.

## 2.0 CAPABILITIES

Timing signals:

| | |
|---|---|
| Code format: | IRIG B |
| Repetition rates: | 100 kHz, 1 pps, 5 ppm, 12 pph |
| Primary frequencies: | 5 MHz (Rubidium oscillator) |
| Other: | can provide 2400 pps (for modem clocks) |

Time accuracy: defined as per accuracy of GPS timing signal > 100 ns.

Frequency accuracy: 5.0 MHz $\pm 5 \times 10^{-11}$ (Rubidium oscillator)

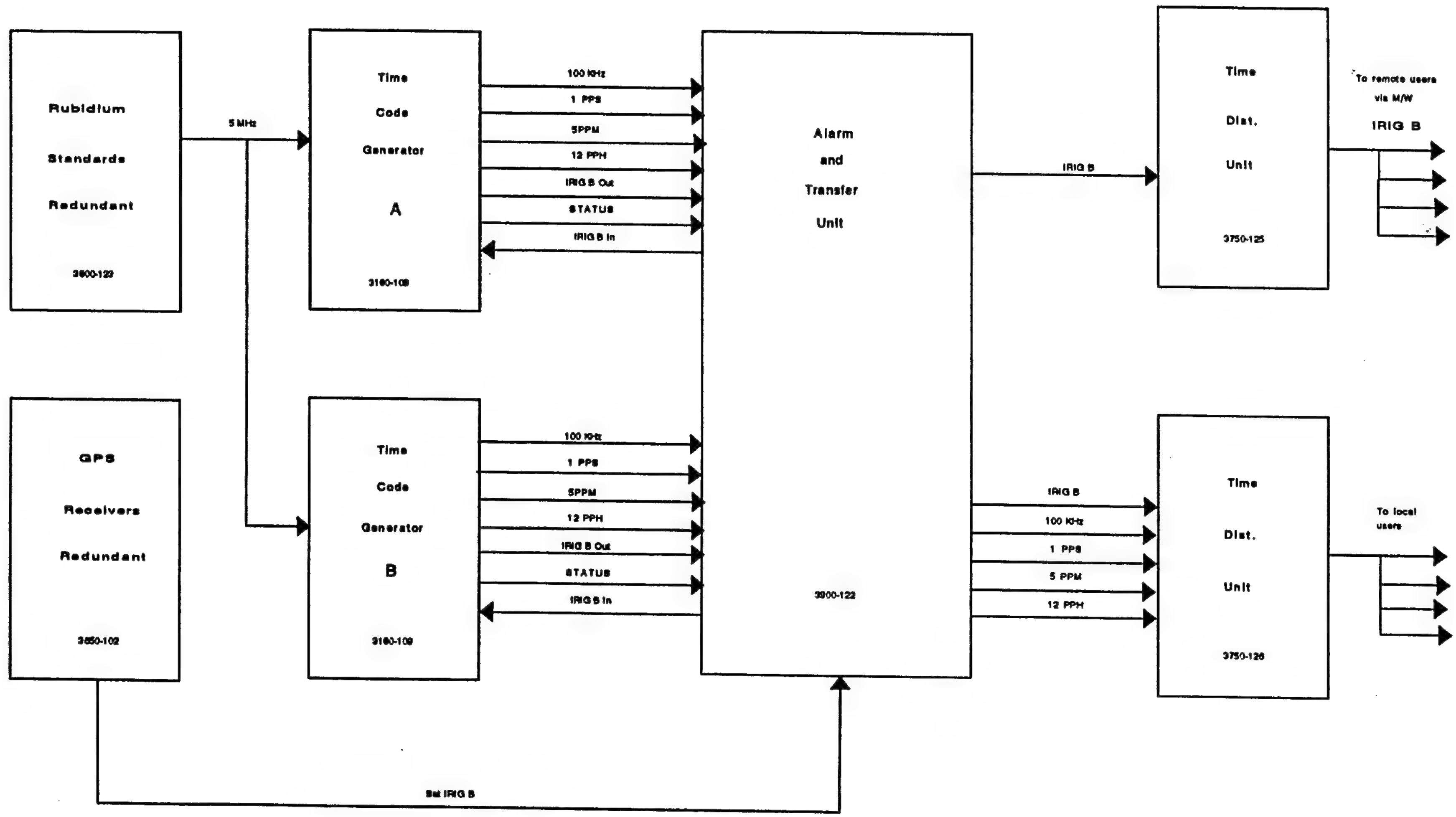
Frequency stability: $< 4 \times 10^{-11}$ /month (Rubidium oscillator)

Availability: 99.9 percent

## 3.0 TIMING SYSTEM DESCRIPTION

The AFWTF timing system was manufactured by Datachron, Inc., Anaheim, California. A high level of reliability is attained by operating in a redundant fashion. As shown in figures 5-1 and 5-2, the system consists of two model 3180 Time Code Generators (TCG) monitored by the model 3900 Alarm and Transfer Unit (ATU). By means of a keyboard on the ATU, one of the two TCGs can be selected as the on-line unit, causing that TCG to be automatically synchronized to UTC via GPS-received IRIG B. The ATU monitors the outputs of both TCGs,

# AFWTF Master Timing System




NOTE: All equipment manufactured by
Datachron.

Figure 5-1. Master Timing System.

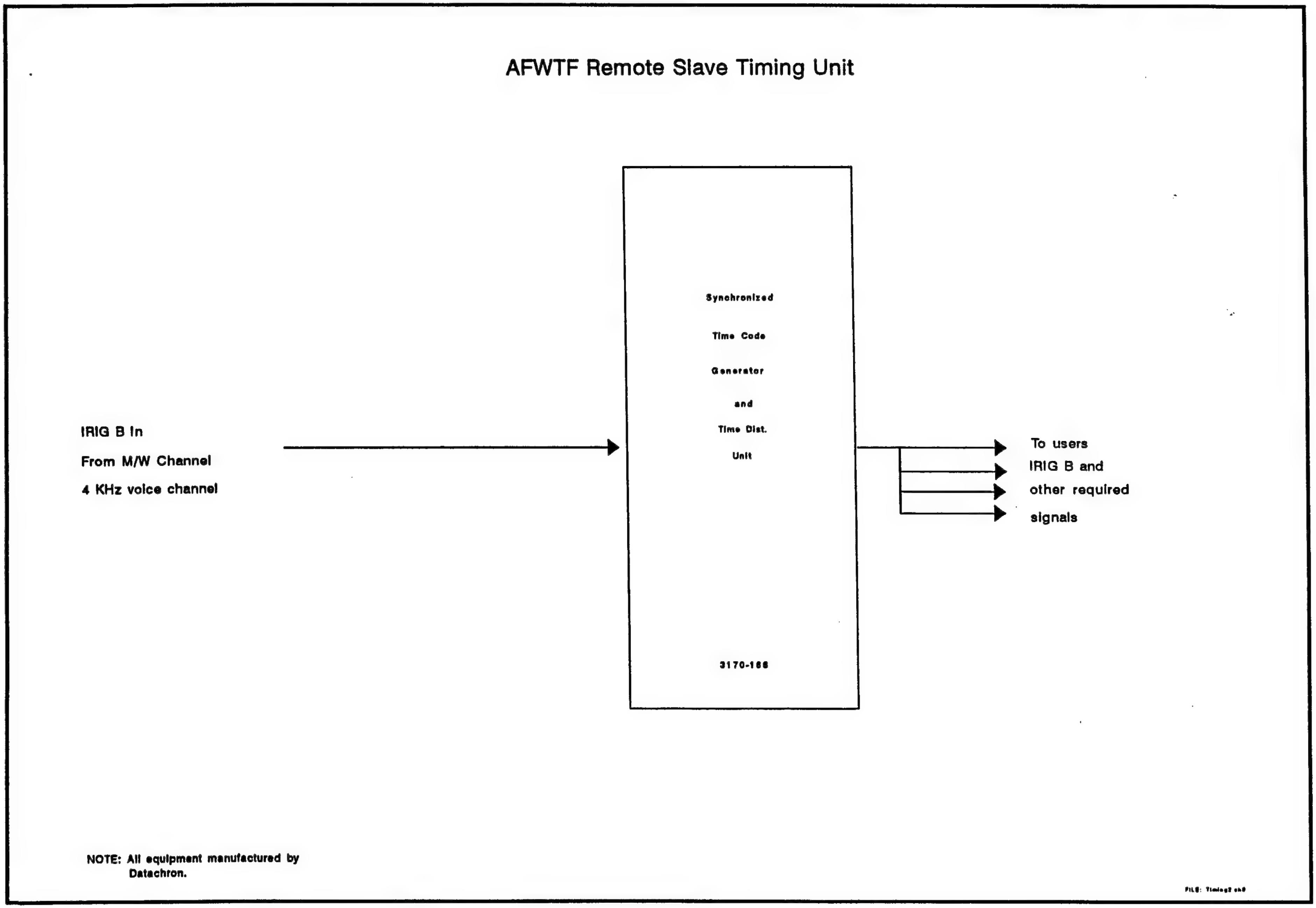



Figure 5-2. Remote slave timing unit.

alerting operators to a failure in either unit and automatically switching to the backup unit on detection of a failure in the primary unit.

Each TCG has a Rubidium Standard as its frequency source. The long term accuracy of these Rubidium Standards is further enhanced by frequency correlating their outputs to GPS data.

The outputs of the selected on-line TCG are presented by the ATU to two Timing Distribution Units (TDUs) models 3750-125 and 3750-126. The model 3750-125 contains distribution amplifiers which interface with the range microwave system for remote distribution of IRIG B signals. The model 3750-126 contains both ac and dc amplifiers for the distribution of timing signals to local users.

System reliability is further enhanced by providing system power via an Uninterruptible Power System (UPS). This UPS provides over 12 hours of power backup to the TCGs, the ATU, the Rubidium Standards, and the TDUs in the event of primary power failure.

At the remote sites, IRIG B is received from the microwave and fed to the Synchronized Time Code Generator (STCG). This unit has adjustable delay compensation to ensure accuracy. The unit generates signals (IRIG B) which are synchronized to the incoming master signal and amplifies them for distribution to the users.

## 4.0 NEAR-TERM PLANNED UPGRADES

None

## 5.0 LONG-TERM PLANNED UPGRADES

None

SECTION 6

# ELECTRONIC PROVING GROUND

## 1.0 INTRODUCTION

The Electronic Proving Ground (EPG) Instrumented Test Range (ITR) provides services primarily for developmental testing of a wide variety of airborne, mobile, and ground based systems for the different military services. The main services provided by the ITR are TSPI, telemetry, electronic environment, and various test support functions as needed.

## 2.0 CAPABILITIES

Timing Signals

Code formats supported are

IRIG A133
IRIG B123
IRIG D122
IRIG E122
IRIG G142

Repetition rates supported are defined by the IRIG Standards

| | |
|---|---|
| IRIG A | 1000 pps |
| IRIG B | 100 pps |
| IRIG D | 1 ppm |
| IRIG E | 10 pps |
| IRIG G | 10,000 pps |

Primary frequencies supported are

| | |
|---|---|
| IRIG A | 10 kHz |
| IRIG B | 1 kHz |
| IRIG D | 1 kHz |
| IRIG E | 1 kHz |
| IRIG G | 100 kHz |

Other

IRIG B is also radiated via VHF radio at 139.025 MHz and 142.125 MHz.

Time Accuracy

Using the current GPS receivers and including the effects of selective availability, the ITR can maintain timing within 150 nsec of UTC. In practice however, timing is usually maintained within 1 μs of UTC which is more than sufficient for most range applications.

Frequency Accuracy

The frequency accuracy of the Central Timing System using the GPS receiver based Disciplined Rubidium Frequency Standard is rated at ±3e-12. At the radar sites using GPS receiver timing, the frequency accuracy is 5 parts in $1 \times 10^{11}$.

Frequency Stability

The frequency stability of the Central Timing System is 3e-11 (Allen Deviation) over a 10-second period. At the radar sites, it is approximately 7e-9 over 10 seconds.

Availability

The Central Timing System timing signals are available 24 hours a day, 7 days a week, and during normal duty hours at the radar sites.

## 3.0 TIMING SYSTEM DESCRIPTION

The Central Timing System uses a GPS receiver based Disciplined Rubidium Frequency Standard as the primary source of 1 MHz. It feeds the primary Time Code Generator as well as an Austron Disciplined Frequency Standard. The disciplined standard continues to provide a high stability 1-MHz signal in the event the GPS Rubidium Standard fails or is otherwise unavailable. The Disciplined Frequency Standard feeds a second time code generator. An ATU monitors the outputs from both generators and will generate an alarm if any key signals are missing or if there are any discrepancies between the two generators. The ATU also selects one of the generators for time code distribution throughout the range as needed.

A LORAN C receiver is used as a primary check of time output against UTC time. A Datum 9390-5020 GPS receiver is used as secondary cross-check.

At the two Fort Huachuca radars, Datum 9390-5500 GPS receivers are used as a primary source of IRIG B timing with hardwire and microwave links to the Central Timing System as backups.

At the two remote instrumentation sites, Datum 9390-5500 GPS receivers along with Sulzer TCXO Frequency Standards are used to feed a Datum 9390 Synchronized Time Code Generator. LORAN C receivers are also used to check the timing. Microwave links are provided to each site from the Central Timing System as a backup timing source. Figures 6-1, 6-2, and 6-3 depict the block diagrams of the Central Timing System, Oatman Mountain Instrumentation site, and Mount Lemmon.

## 4.0 NEAR-TERM PLANNED UPGRADES

In September 1994, EPG's old FTS-4050 Cesium Beam Standard was declared unrepairable by the manufacturer. Rather than spend more than $25,000 for a new one, it was replaced by a Truetime XL-DC601 GPS receiver based Disciplined Rubidium Frequency Standard. The EPG is trying to purchase another Truetime unit as a backup. Each of these receivers cost $9,000 which represents a significant savings over the cost of a new cesium unit.

## 5.0 LONG-TERM PLANNED UPGRADES

When funding can be obtained, the existing Datum GPS units at each of the other instrumentation sites will be replaced with newer Truetime units, which will improve the timing accuracy at each site by a factor of two. It is hoped that the newer units will prove more reliable, thus saving on costs of repairs by the manufacturer.

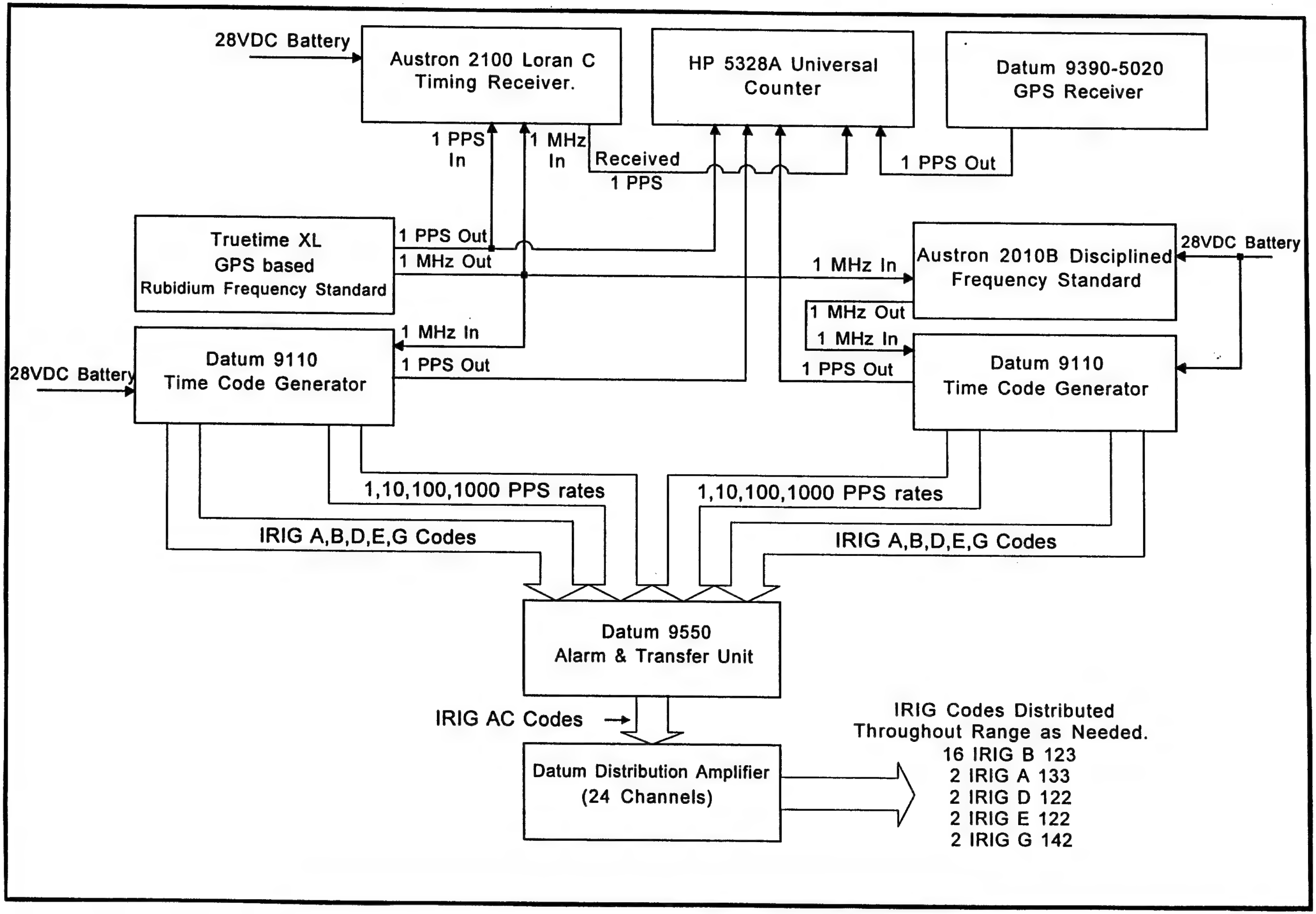



**Figure 6-1. Central timing system block diagram.**

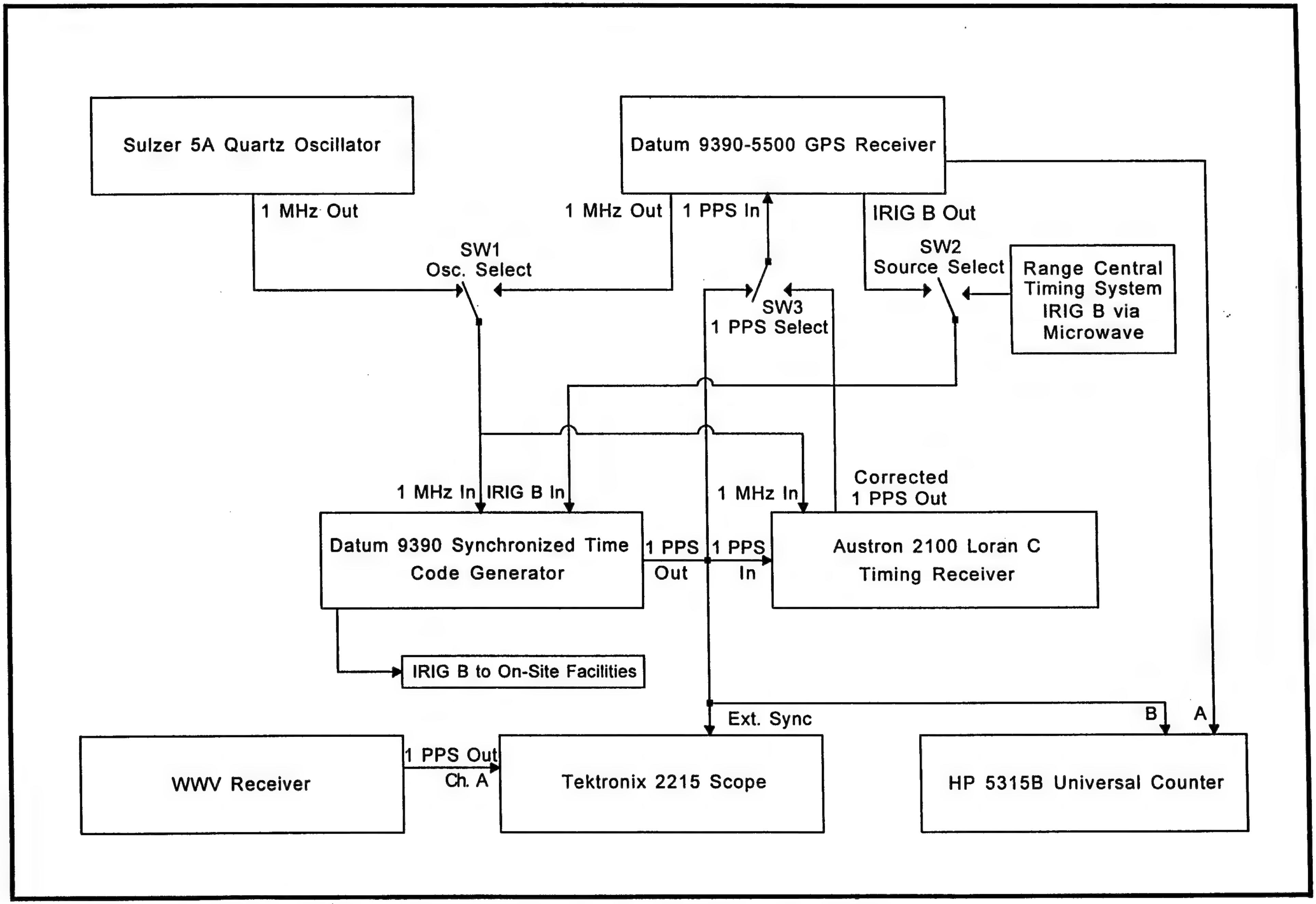



Figure 6-2. Oatman Mountain instrumentation site timing system block diagram.

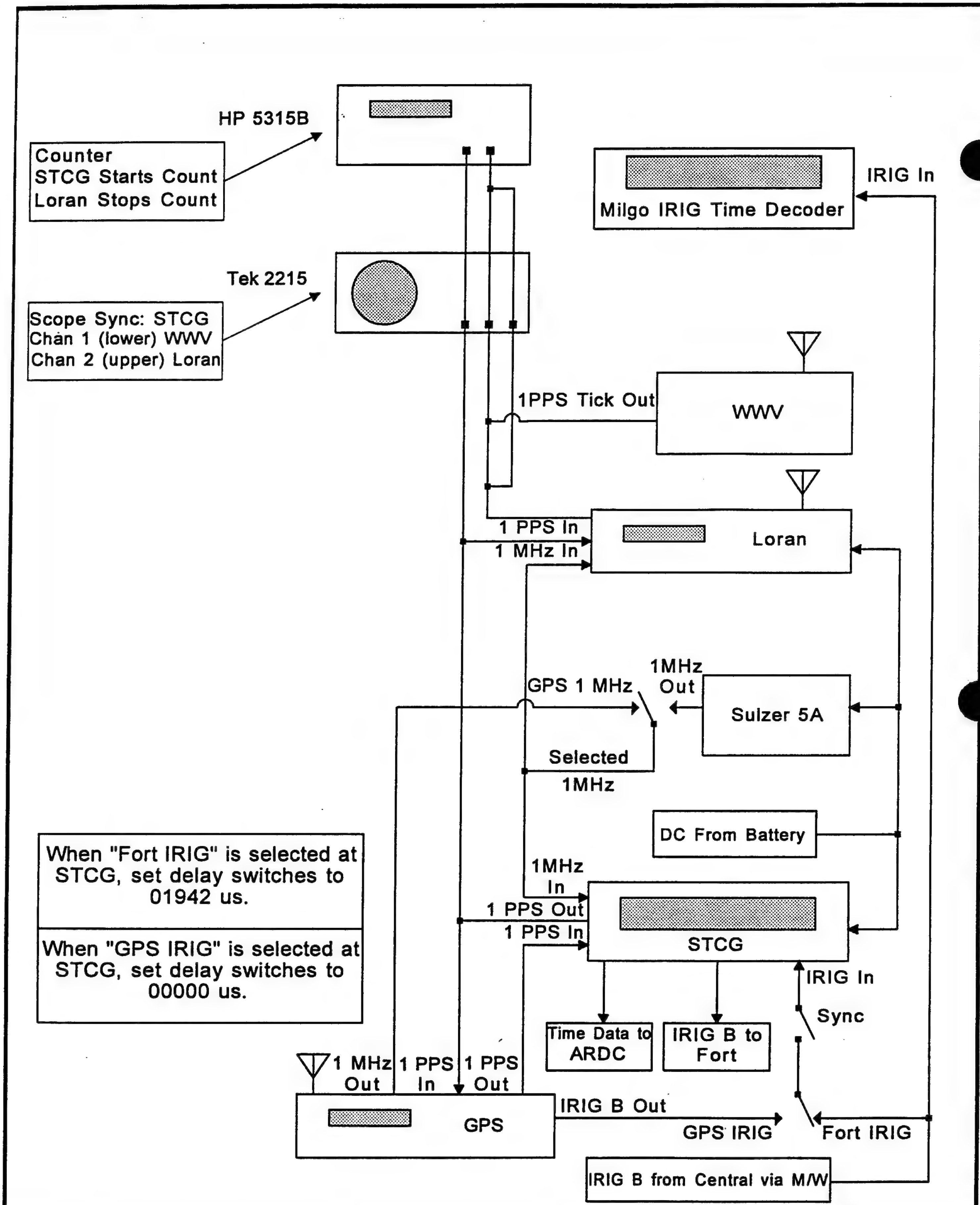



Figure 6-3. Mount Lemmon timing system block diagram.

SECTION 7

# NAVAL AIR WARFARE CENTER WEAPONS DIVISION - CHINA LAKE (NAWCWPNS (CL))

## 1.0 INTRODUCTION

The timing function is part of the Range Support Branch, Data Systems Division, Range Department. The mission of the timing group is to provide range customers with highly accurate and precise time-of-day information, remote control functions, and Targets Acquisition and Designation System (TADS) data.

## 2.0 CAPABILITIES

Precise time of day includes IRIG time code formats B (ac), A (dc) and H (dc) which are broadcast on 1780 and 1792 MHz. IRIG E (ac), IRIG A (ac) and 5 MHz are distributed to the Range Control Center users via cables.

Remote control functions include camera starts, target radar (on/off), sequencer (on, off, reset), and various other requests.

Target Acquisition and Designation System information directs the instrumentation sites to the targets.

Time and frequency accuracies/stability are provided by a Cesium Beam Frequency Standard. Time-of-day accuracy is maintained at 1 microsecond or better. The 5 MHz output from the cesium is provided as the clock source for the AT&T Digital Access Cross Connect System (DACS) in the communications center. The output synchronizes all data coming through the communications center of the Range Control Center (RCC).

Broadcast information is available to all sites that have a range time receiver (see figure 7-1) and line of site to the transmitter stations. All of the time codes and pulse rates generated in the Timing Center are available throughout the RCC via cable distribution.

## 3.0 TIMING SYSTEM DESCRIPTION

The UHF timing system operates in the 1700-1800 MHz upper L band. It is a five-channel system that includes three IRIG standard time codes (see table 7-1), TADS data, and a tone control channel. Each channel is a separate subcarrier oscillator (SCO) modulated by its respective data. The SCO signals are combined to form a composite signal which, in turn, modulates the various FM transmitters (see figure 7-2). The main NAWCWPNS (CL) test ranges are covered by transmitters located at "B" Mountain (1780 MHz) and Cinder Peak (1792 MHz) (see figure 7-3).

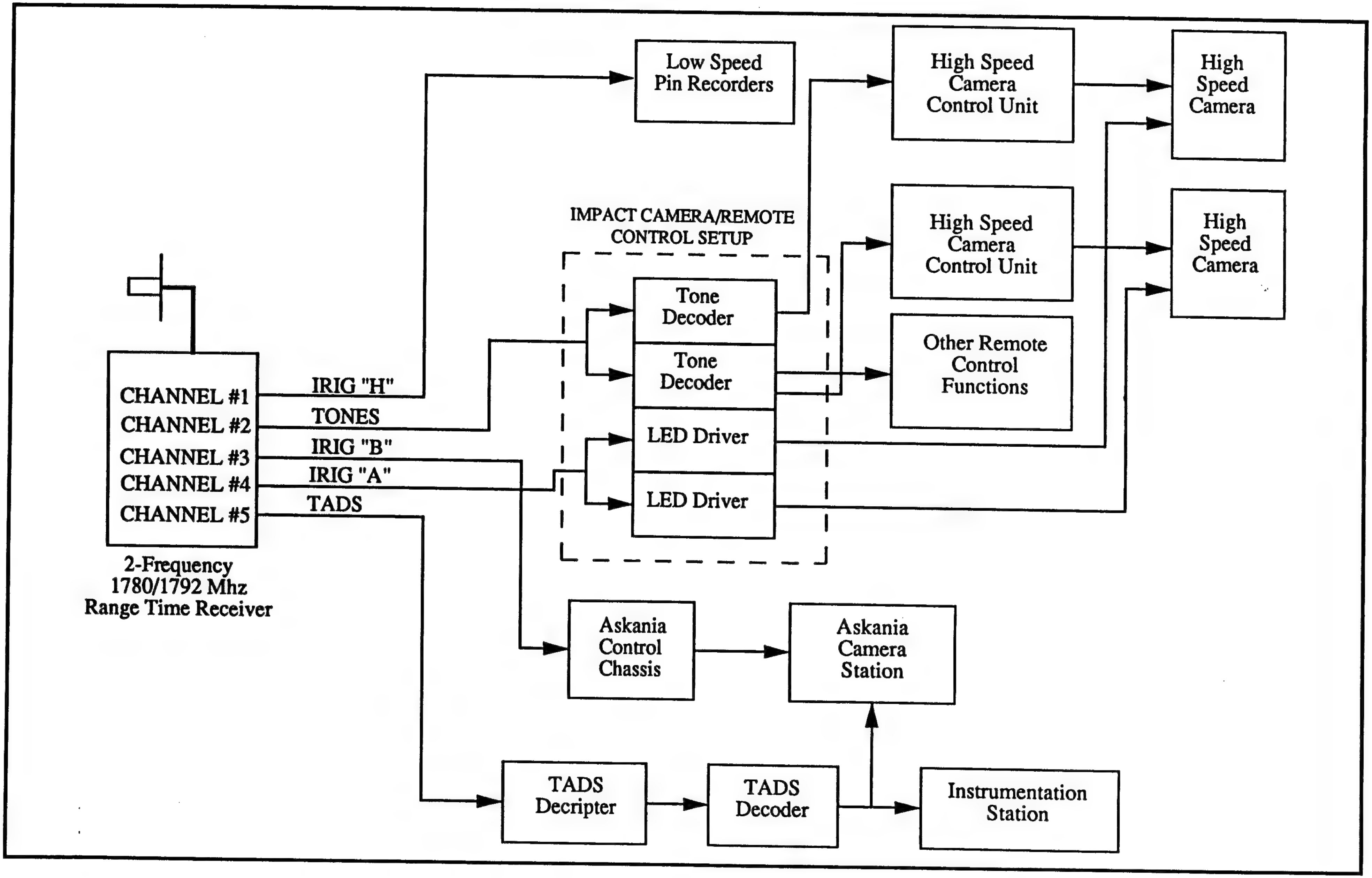



Figure 7-1. Timing receiver output functions.

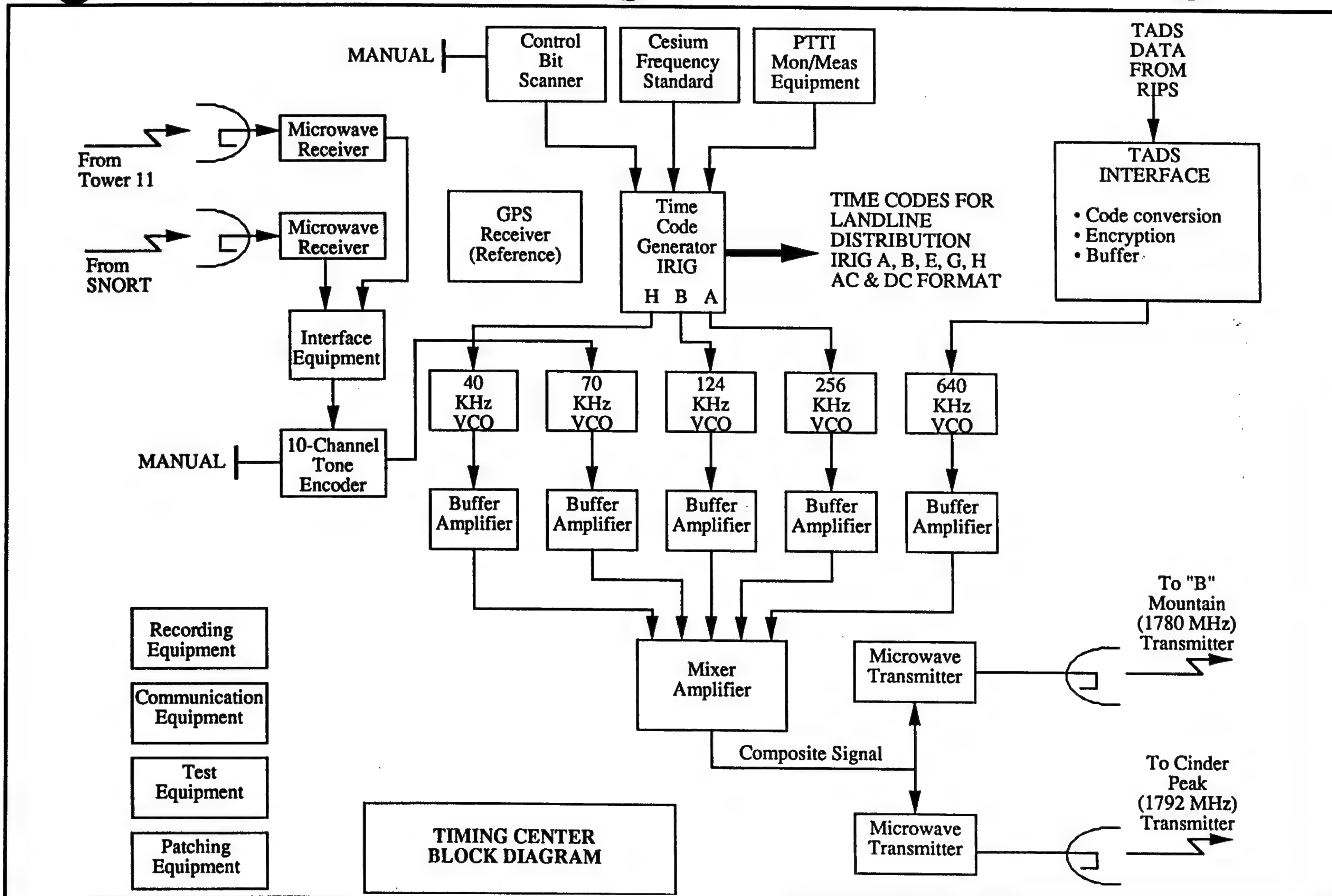



Figure 7-2. Timing center block diagram.

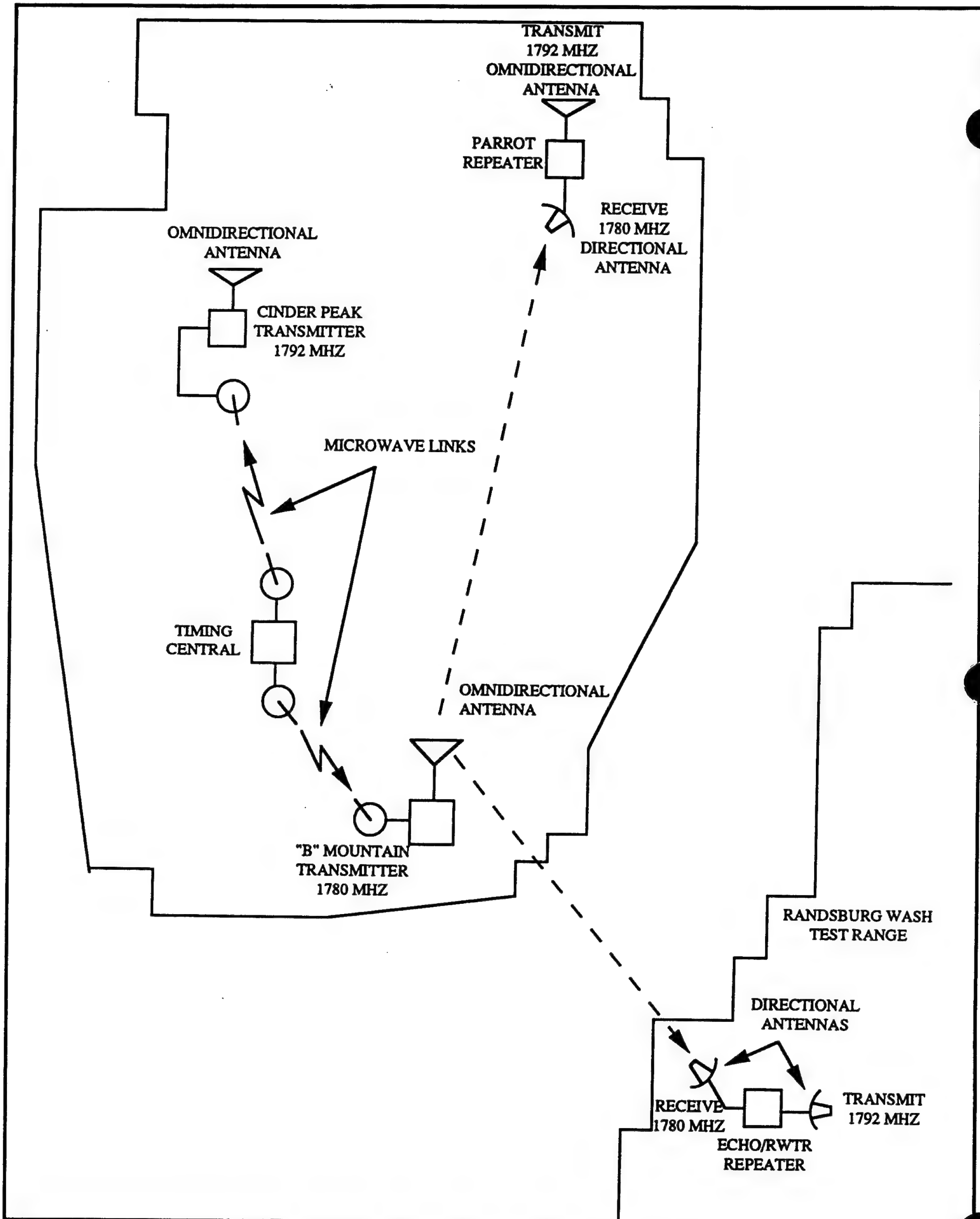



**Figure 7-3. UHF timing system transmitter/repeater locations.**

Because Echo Range and RWTR cannot receive transmissions from either "B" Mountain or Cinder Peak directly, a repeater was established at Echo Range Sea Site-1 to cover those areas (see figure 7-2). This repeater receives the signal from "B" Mountain (1780 MHz) and retransmits on (1792 MHz). The range is in the process of moving the repeater site to a different location (Slate) which will give better coverage of instrumentation sites.

Similarly, since Junction Ranch and the Coles Flat area cannot receive direct transmissions from "B" Mountain or Cinder Peak, a repeater has been established at Parrot Peak to cover those areas (see figure 7-2). This repeater also receives the signal from "B" Mountain on 1780 MHz and retransmits on 1792 MHz. Omnidirectional transmit antennas are used at the main transmitter sites and also at the repeater sites.

The IRIG time code formats are broadcast in time-of-day accuracy dependent upon the capability of the frequency standard at Timing Central. The tone channel is used as a remote event control system. Remote cine-cameras, for example, are started via this channel. Ten tones are available, and control of these tones is maintained at Timing Central. The TADS data is used by instrumentation stations to find and track targets. An atomic frequency standard and sophisticated time setting-monitoring equipment in the Timing Center is used to maintain time-of-day accuracies of better than 1 microsecond.

TABLE 7-1. UHF TIMING SYSTEM TIME CODES

| IRIG Format | Signal Waveform | Signal Element Rate, pps | Time Frame Rate |
|---|---|---|---|
| A | dc level shift | 1000 | 10/s |
| B | modulated carrier (1 KHz) | 100 | 1/s |
| H | dc level shift | 1 | 1/min |

## 4.0 NEAR TERM PLANNED UPGRADES

The range will continue to operate and to maintain the present system. The purchase of GPS receivers to meet new system requirements is also in the near-term plans.

## 5.0 LONG TERM PLANNED UPGRADES

Plans are to replace range time receivers with GPS receivers. The remote control function will be a separate standalone system. The capabilities of the TADS system will be increased to cover a broader area, and TADS data will be broadcast as a single signal.

## SECTION 8

## SEA TEST RANGE
## NAVAL AIR WARFARE CENTER WEAPONS DIVISION (POINT MUGU)
## INSTRUMENTATION TIMING CENTER

### 1.0 INTRODUCTION

The Sea Test Range timing system consists of two timing centers that have triple redundant Time Code Generators. One center is located at Point Mugu and the other is located at San Nicolas Island. Cesium Beam Frequency Standards are used as the time base at both centers. Both timing centers use Global Positioning System (GPS) receivers to achieve a reference synchronized to ±100 nanoseconds of the Coordinated Universal Time (UTC) maintained by the U. S. Naval Observatory (USNO). The combination of daily GPS synchronization and a very stable time base allows the timing system to exceed the 1 microsecond requirement of the range. LORAN C and WWV receivers are available for use as backup reference sources to the GPS receivers.

The time code generators provide Interrange Instrumentation Group (IRIG) standard codes A, B, E, G, and H as well as certain specialized timing signals (see below). The timing codes are distributed to instrumentation and launch sites throughout the Sea Test Range via copper cables. IRIG B is also transmitted over two UHF frequencies for use by ships and aircraft.

Portable time code generators equipped with Cesium or Rubidium Standards and internal batteries are provided when a range user is located off the Sea Test Range. Synchronization generators are used to correct for propagation delay from cables.

### 2.0 CAPABILITIES

| IRIG TIMING SIGNALS AVAILABLE AT POINT MUGU | | | |
|---|---|---|---|
| FORM | | CARRIER FREQUENCY | CODED EXPRESSIONS |
| IRIG A | SINE WAVE | 10 kHz | BCD, SBS |
| IRIG B | SINE WAVE | 1 kHz | BCD, CF, SBS |
| IRIG E | SINE WAVE | 100 Hz | BCD |
| IRIG E | SINE WAVE | 1 kHz | BCD |
| IRIG G | SINE WAVE | 100 kHz | BCD |
| IRIG H | SINE WAVE | 1 kHz | BCD |

BCD is Binary Coded Decimal
CF is Coded (Control) Function
SBS is Straight Binary Seconds

The following timing signals are also available:

| | |
|---|---|
| 10 Mhz | 100 k |
| 5 Mhz | 82 kHz |
| 1 Mhz | 1 kHz |

Amplitude modulation (AM) transmitted 138.42 kHz modulated by IRIG B
Amplitude modulation (AM) transmitted 254.0 kHz modulated by IRIG B

The time accuracy is 1 microsecond.

The frequency accuracy is 15 nanosec max drift per day.

The frequency stability is 2 x 10 (-9) parts per cycle per second.

The availability is 24 hours a day.

## 3.0 TIMING SYSTEM DESCRIPTION

Three cesium beam oscillators serve as the frequency standards. One is the primary and the other two are alternates. All are in continuous operation. The cesium oscillators output a 5-MHz signal to the time code generators.

The time code generators in turn provide IRIG and other timing signals to the Alarm and Transfer Unit (ATU). The ATU compares the outputs of all three time code generators. If the primary time code generator is off, it switches to an alternate time code generator. If a nonprimary time code generator is off, an alarm light is lit (see figure 8-1).

## 4.0 NEAR-TERM PLANNED UPGRADES

One short term objective is to upgrade the San Nicolas Island (SNI) Timing Center. The timing accuracy requirement for SNI is the same as it is for Point. Mugu. Obsolete and outdated equipment needs to be replaced. Remote control and monitoring with synchronization of the SNI Timing Center equipment will reduce future requirements for replacement of expensive Cesium Standards and minimize the requirement for SNI operations personnel.

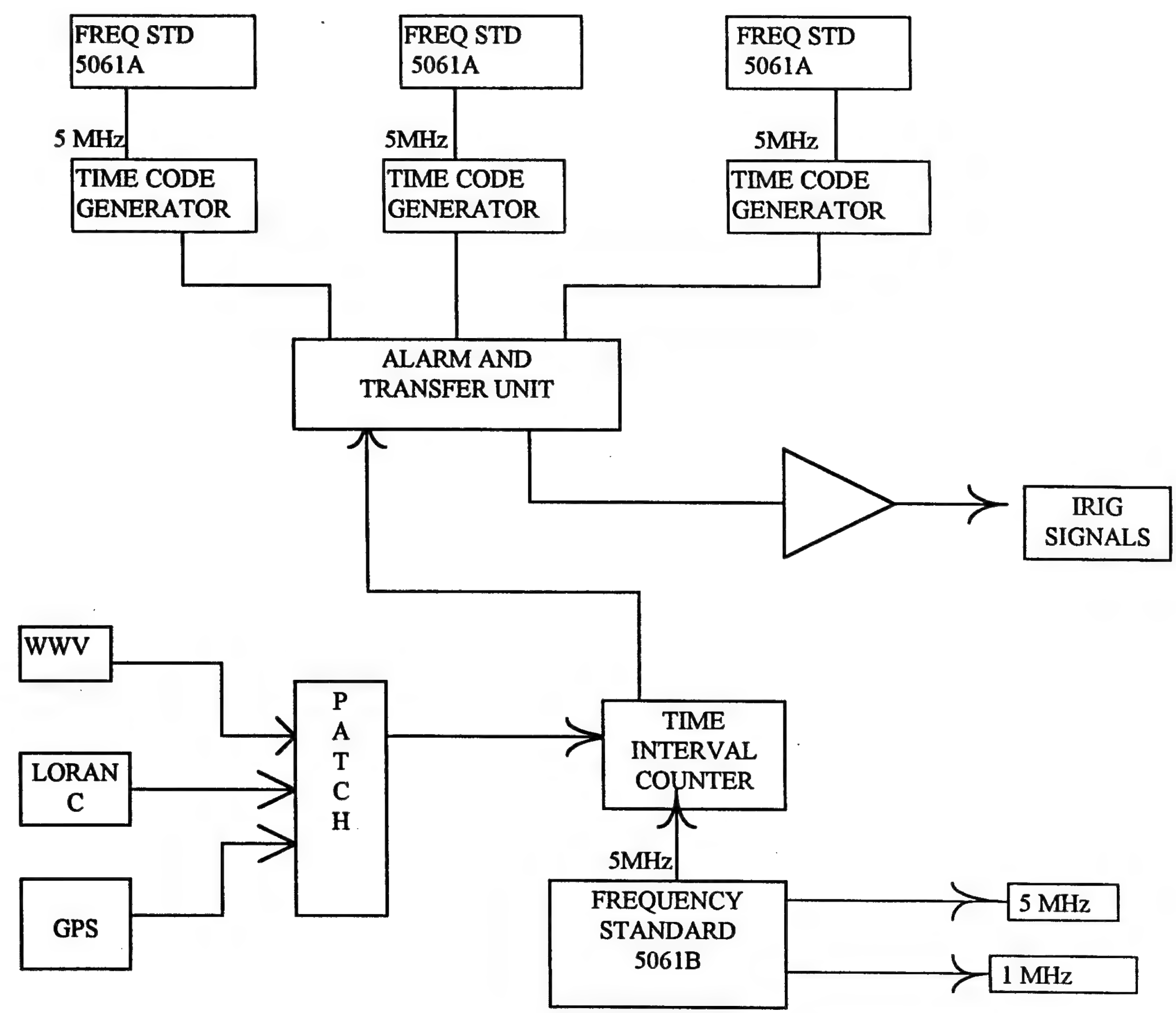



**Figure 8-1. Sea Test Range timing system block diagram.**

Existing GPS receivers need to be replaced with receivers that have the capability of working with the current satellites. Much of the existing timing distribution and terminal equipment needs to be replaced with more reliable and higher quality equipment for test operations.

## 5.0 LONG-TERM PLANNED UPGRADES

The long-term need is to upgrade the timing center, distribution equipment, and terminals to sustain quality timing support for test operations.

SECTION 9

# NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION (NAWCAD)
# PATUXENT RIVER, MARYLAND
# RANGE TIMING SYSTEM

## 1.0 INTRODUCTION

The NAWCAD Central Range Timing System is a GPS-referenced timing distribution system which provides IRIG-B timing via cable distribution and both UHF and VHF radio transmissions to the warfare center complex. The timing system is maintained and operated by

Test and Evaluation Group
Atlantic Ranges and Facilities Department
Telemetry Division
Code 513100A
POC: Steve Williams or Jack Wingate,
DSN 342-1726, Commercial (301) 342-1726

## 2.0 CAPABILITIES

| | |
|---|---|
| Timing Signals | |
| Code format: | IRIG B122 |
| Repetition rates: | 1 kpps, 100 pps, 10 pps, 1pps |
| Primary frequencies: | 1 MHz |
| Other: | IRIG A, E, and H codes available at timing site |
| Time Accuracy: | less than 2 microseconds from UTC (USNO) |
| Frequency Accuracy: | synchronized to GPS |
| Frequency Stability: | synchronized to GPS |
| Availability: | continuous 24 hours a day, 7 days a week |

## 3.0 TIMING SYSTEM DESCRIPTION

The Central Range Timing System is depicted in figure 9-1. It consists of two TrueTime model 805-363 GPS time code units, a Datum 9390-100 synchronized generator, cable distribution equipment, a UHF AN/GRT-22 10-watt transmitter and a VHF Mosely PCL-101 transmitter with Mosely AMP150-R 70-watt amplifier.

The two model 805 GPS time code units are both maintained on-line, independently receiving GPS satellite transmissions. One unit is manually selected to

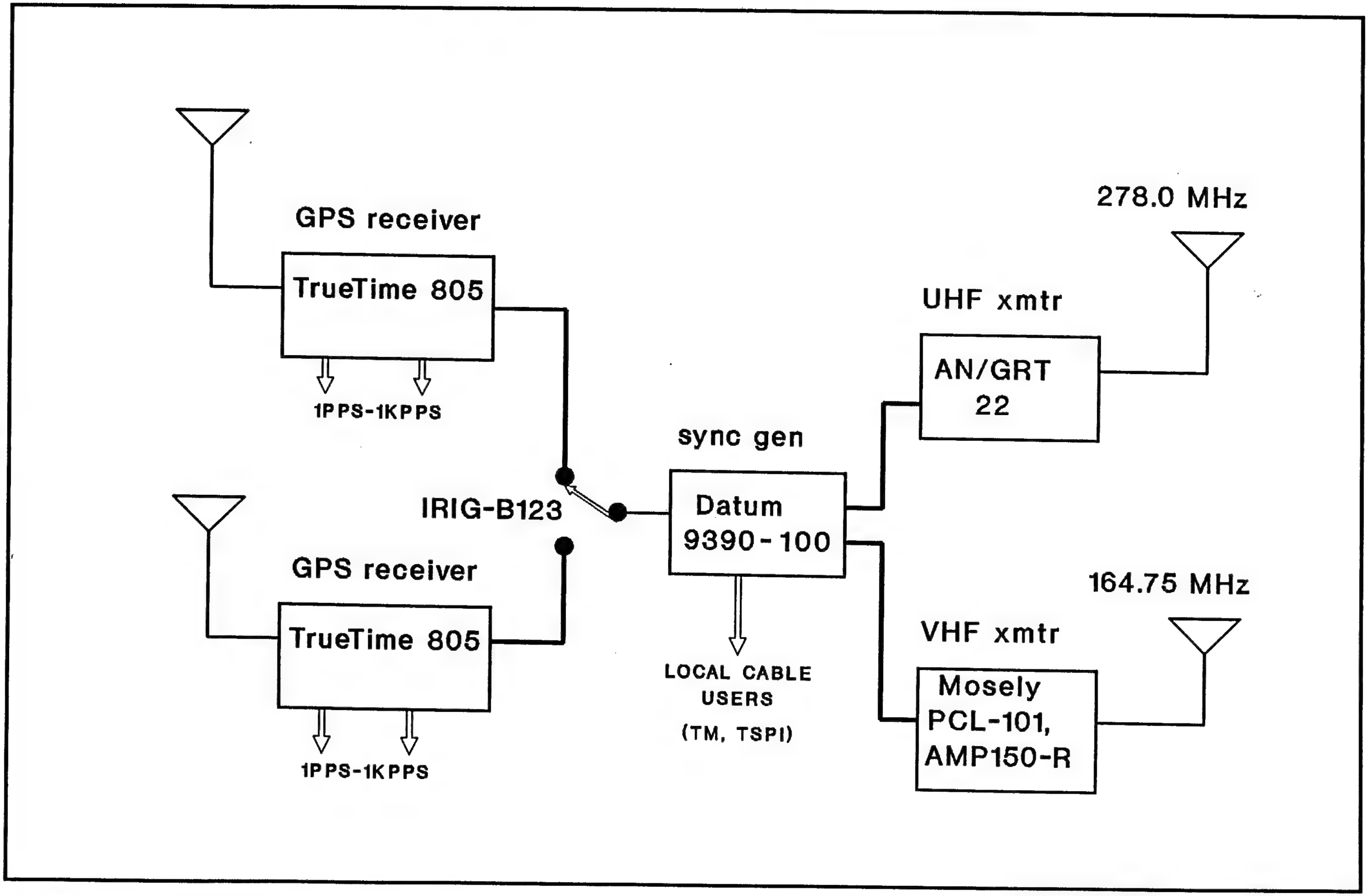



Figure 9-1. NAWCAD range timing system.

drive the 9390 synchronized generator from its IRIG B122 (1 kHz amplitude modulated) output. The 9390 provides IRIG B122 locally via its cable drivers to the Telemetry Data Center and the Chesapeake Test Range, and via twisted pair cable to the UHF and VHF transmitter sites elsewhere on the base. The UHF transmitter maintains continuous timing on 278.0 MHz for jam syncing aircraft time generators on the flight line from the standard aircraft UHF AM radio. The FM-modulated VHF transmitter maintains continuous timing on 164.75 MHz for aircraft equipped with a special timing receiver. Usable range exceeds 50 miles for jam syncing time generators using this capability.

## 4.0 NEAR-TERM PLANNED UPGRADES

Add a hot-standby automatic switchover capability between the two TrueTime GPS receivers and add battery back-up for the GPS receivers and the synchronized generator.

## 5.0 LONG-TERM PLANNED UPGRADES

Replace the Datum synchronized generator and add improved line drivers and a fiber optic cable interface.

## SECTION 10

## SANDIA NATIONAL LABORATORIES
## KAUAI TEST FACILITY

### 1.0 INTRODUCTION

Sandia National Laboratories, Kauai Test Facility (KTF) provides test support for the Department of Energy (DOE) Weapons Research and Development activities. To make maximum use of the facilities, Sandia undertakes selected reimbursable projects from other government agencies on a noninterference basis with DOE programs.

Located in Hawaii, KTF is on the west side of Kauai Island. The facility is incorporated within the U.S. Navy Pacific Missile Range Facility (PMRF). Original missile launches were conducted to acquire scientific data in support of atmospheric nuclear testing. More recent operations have focused on the science and technology necessary to develop weapons.

The Kauai Test Facility provides a high-quality, integrated facility for conducting a wide range of test operations. These operations support research and development testing of materials, components, and advanced reentry vehicle technologies. Experiments are conducted in the upper atmosphere, the ionosphere, and in space. Facilities are also available for water-impact and water-entry experiments using high velocity test vehicles.

Resources are available for assembling, testing, launching, tracking, and recovering instrumented rockets, rocket payloads, and aircraft payloads. The telemetry ground station provides receiving, recording, and quick-look playback of radio telemetered test data. In addition, optical tracking and photometrics coverage of test objects and experiments are available.

### 2.0 CAPABILITIES

The central timing system at KTF provides two different serial time codes that can be distributed for time tagging events occurring during an experiment. The timing system also provides four separate pulse rates which may be used to synchronize equipment used during an experiment.

The two time codes generated by the timing system are the IRIG A and IRIG B serial time codes. The detailed format descriptions of these time codes are defined in IRIG Standard 200-95, <u>IRIG Serial Time Code Formats</u>, as A130 and B120.

The IRIG B serial time code repeats once per second and has a timing resolution of 1 millisecond. The IRIG-A serial time code repeats every 100 milliseconds and has a timing resolution of 0.1 millisecond. The time code signals generated at KTF can be maintained to an accuracy of within 1 microsecond to UTC.

## 3.0 TIMING SYSTEM DESCRIPTION

The KTF central timing system consists of three time code generators (TCGs) and one ATU. The time code generators are Datum model 9100-9143 Synchronized Time Code Generators. The ATU is a Datum model 9550-834. A block diagram of the central timing system is shown in figure 10-1.

The time code generators are operated as synchronized time code generators. In this mode, the TCGs synchronize to an input time code signal. Once synchronized, the TCGs produce output timing signals that are in time-synchronization with the input time code signal. If the input time code signal is lost, the TCG will automatically change to generate mode and continue to produce the output timing signals. The PMRF supplies an IRIG-B timing signal to KTF which is used as the master timing reference. This signal is routed through the ATU to the TCGs. In the event that the signal from PMRF is lost, the ATU will automatically route the IRIG B signal from TCG 1 to the inputs of the other two TCGs.

Each time code generator is capable of generating both IRIG A and IRIG B serial time codes. Each unit also generates a parallel time-of-day output. This output contains time-of-year information (milliseconds through days) in BCD (binary code decimal) format. The TCGs also provide the following pulse rates: 1 pps (pulse per second), 10 pps, 100 pps, and 1000 pps.

Each time code generator's internal time base is a high stability temperature-controlled crystal oscillator. The oscillator operates at a frequency of 1 MHz. Its temperature stability is better than $\pm 3 \times 10^{-8}$ over a temperature range of 0 to 60° Centigrade. The oscillator's aging or drift rate is less than $\pm 5 \times 10^{-9}$ per day.

The Datum time code generators have a video time insertion option. This option allows time-of-day information to be inserted into a composite video signal from a video camera.

The ATU is designed to monitor the IRIG A and IRIG B time codes and the pulse rate outputs from the three time code generators. The PMRF IRIG-B reference timing signal is also monitored. The time code inputs are monitored for amplitude variations below a selectable limit. The IRIG A and B code inputs are monitored for bit errors. Audible and visible outputs are supplied for all alarm conditions.

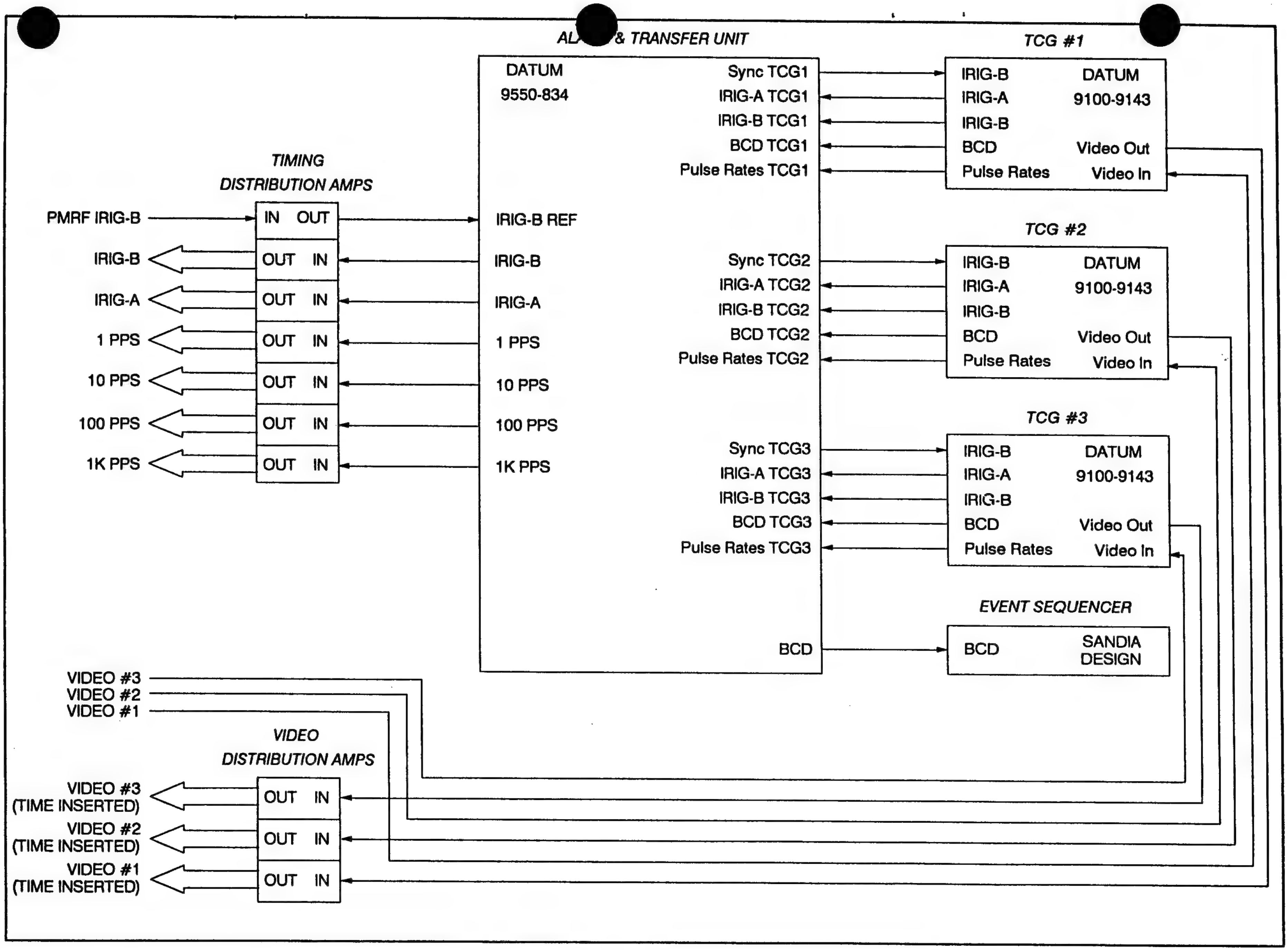



Figure 10-1. Kauai Test Facility timing system block diagram.

The ATU provides two methods for placing the outputs of one of the TCGs on-line. The outputs of any one TCG may be selected manually or automatically. When a TCG is selected manually, the ATU provides full monitoring capability but no redundancy in case of a TCG failure. The automatic mode provides both full monitoring capability and triple redundancy. In the automatic mode, the outputs of TCG 1 are designated as the primary and are selected for output. In the event of a detected fault in the primary TCG, its outputs are taken off line and the outputs of TCG 2 are placed on line. If there is a pre-existing fault in TCG 2, then TCG 3's outputs will be placed on line. If both TCG 2 and 3 have faults, then no output switch would occur.

An in-house Sandia designed event sequencer is used for precisely initiating events during range operations. This unit provides 32 separate channels of relay closure outputs. Each channel is preloaded with the time of year (millisecond resolution) of when to activate. When coincidence occurs between the preloaded time of year and the input BCD time of year, the channel's output is activated. Duration of the channel's relay closure is also programmable.

## 4.0 NEAR-TERM PLANNED UPGRADES

An event count status system will be added to the current timing system. This system will be used by both PMRF and KTF to generate event count status for visual display during rocket launches occurring at either facility. Event count status will be generated by master clocks at either site for local display and for display at the other facility.

## 5.0 LONG-TERM PLANNED UPGRADES

A GPS timing receiver may be added to the existing timing system. This unit would be used to replace or augment the PMRF IRIG-B timing signal and enhance KTF's ability to make time and frequency measurements.

# SECTION 11

# TEXCOM EXPERIMENTATION CENTER
# FORT HUNTER LIGGETT

## 1.0 INTRODUCTION

The primary mission of Test and Experimentation Command (TEXCOM) Experimentation Center (TEC) is to instrument and perform experiments on various weapon systems and equipment. The TEC usually performs these experiments using Real Time Casualty Assessment.

## 2.0 CAPABILITIES

Timing Signals:

Code format: IRIG B

Repetition rates: Continuous (1 second as per IRIG B)

Primary frequencies: FM 143.2 MHz

Time accuracy: ±1.5 ms of UTC/NBS when corrected for propagation delay through onboard switches using the A-468MS antenna.

Frequency accuracy: N/A as per GEOS satellite

Frequency stability: N/A as per GEOS satellite

Availability: 24 hours a day

## 3.0 TIMING SYSTEM DESCRIPTION

Refer to figure 11-1.

## 4.0 NEAR-TERM PLANNED UPGRADES

Convert to a GPS timing system. At the present time, TEC is surveying industry vendors of GPS timing receivers.

## 5.0 LONG-TERM PLANNED UPGRADES

None other than near-term upgrades.

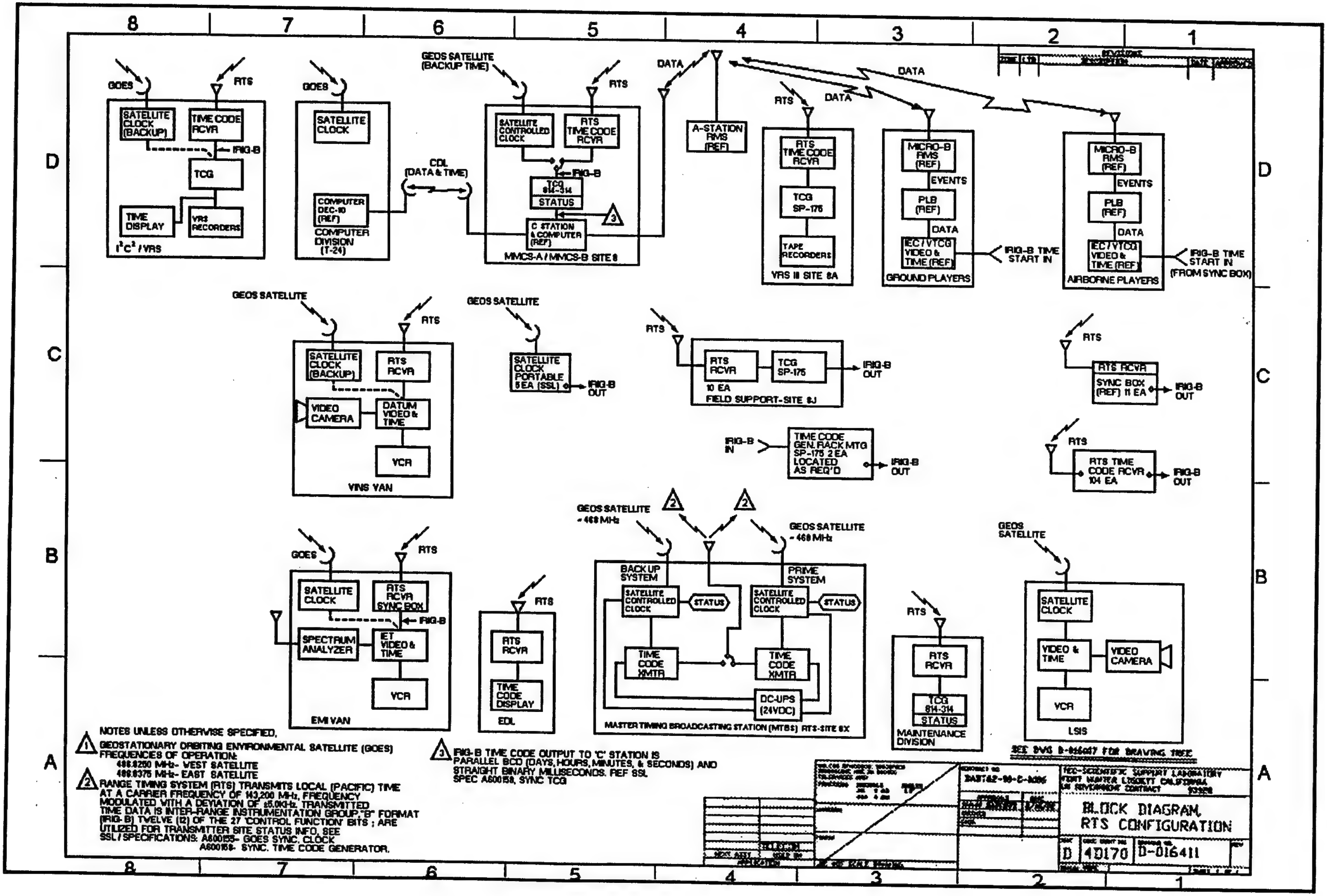


Figure 11-1. Timing system block diagram.

# SECTION 12

# U.S. ARMY DUGWAY PROVING GROUND
# DUGWAY, UTAH

## 1.0 INTRODUCTION

The U.S. Army Dugway Proving Ground's mission is field, chamber, and laboratory testing of chemical and biological defensive systems. Most testing is done locally; however, occasional travel is necessary to conduct testing of smoke and obscurant and illumination devices.

## 2.0 CAPABILITIES

Dugway Proving Ground used WWVB for range timing transmitted over a "modified voice transmitter" which covered a radius of approximately 60 miles. In remote locations where WWVB range time was not received, Geostationary Operational Environmental Satellite (GOES) receivers were used with IRIG B amplifiers to provide timing to the user on site. Recently, four Global Positioning System (GPS) receivers were added.

## 3.0 TIMING SYSTEM DESCRIPTION

At the present time, DPG has four Kinemetric GPS receivers. One is installed in Dugway's Calibration Laboratory. In addition to the GPS receivers, Yuma Proving Ground supplied some cesium beams which are used to keep the GPS receiver calibration current. The signal received from the GPS receiver is then sent by microwave (approximately 20 miles) where it is fed into a modified voice transmitter to broadcast time to the range.

## 4.0 NEAR-TERM PLANNED UPGRADES

Because the transmitter has proven to be inadequate, action has been taken to replace it. An AACOM IRIG transmitter will be delivered 15 September 1995. By 1 October 1995, Dugway's upgrade of its timing system should be in place and fully operational.

## 5.0 LONG-TERM PLANNED UPGRADES

Long-term plans include the procuring of more timing amplifiers and GPS receivers.

Point of contact is Mr. David Clement or Mr. Randy Reed at DSN 789-5361.

## SECTION 13

## U.S. ARMY YUMA PROVING GROUND
## RANGE TIME SYSTEM

### 1.0 INTRODUCTION

The U.S. Army Yuma Proving Ground (USAYPG) is located on approximately 1 million acres of desert terrain in southwestern Arizona. A wide variety of Army and Department of Defense test programs are conducted on several highly instrumented ranges. These programs involve testing of ammunition, weapons and weapon systems, tank and automotive vehicles, air delivery systems, aircraft armament systems, and other various test programs. A range time station and distribution system has been developed to supply required IRIG timing signals to instrumentation sites and test support facilities.

### 2.0 CAPABILITIES

The following range timing system capabilities are provided.

Timing Signals:

Code format: IRIG B (B122)

Repetition Rate: 100 pps

Primary Frequencies: 1 kHz carrier modulation

Others:
Master Range Time Station VHF - 150.765 MHz
Windy Mountain Repeater VHF - 150.500 MHz

Time Accuracy: On-time signals are derived from the Global Positioning System (GPS) and the following applies:

GPS Time ±100 ns
UTC-USNO Time ±150 ns with Selective Availability OFF
UTC-USNO Time ±300 ns with Selective Availability ON

Frequency Accuracy: Accuracy of the disciplined rubidium oscillator is maintained through temperature-compensated circuitry under microprocessor control. The rubidium oscillator is disciplined to GPS which removes all long term errors including aging effects.

Accuracy - $1.0x10^{-11}$, typically $5x10^{-12}$

Frequency Stability:

Short-Term Stability - $<1.0x10^{-10}$ ($t^{-0.5}$) for
1 sec $\leq$ t $\leq$ 100 sec.
$1.0x10^{-11}$ after 24 hours,
typically $5x10^{-12}$

Long-Term Stability - $1.0x10^{-12}$ for 30 days
$5.0x10^{-13}$ for 60 days
The stability approaches that of UTC-USNO
over longer periods.

Availability: The YPG range timing system is normally available 24 hours a day, 7 days a week. Loss of ac power to the RF transmitter will cause a loss of range time transmission and distribution to the instrumentation sites and facilities.

## 3.0 TIMING SYSTEM DESCRIPTION

The YPG timing system is comprised of a master range timing station, a repeater timing station, and the receivers used in the field at instrumentation sites and at support facilities. The following paragraphs provide a breakdown description of the timing system.

Master Range Timing Station. The master timing station is comprised of several off-the-self commercial components. Figure 13-1 provides a block diagram outlining the interfacing of these components into a range timing station. A description of purpose and operation of these components follows.

Time Source/Frequency Standard. The time reference, frequency standard, and IRIG time code generation are provided by two TrueTime model GPS-DC MK III receiver units. The MK III computes accurate time and position derived from Course Acquisition (C/A) signals from the GPS. The GPS data are used to generate the IRIG B122 signals which modulate the RF FM transmitters. System clocking is provided by two GPS disciplined rubidium oscillators which furnish internal clocking to the MK IIIs and external clock frequencies of 1, 5, and 10 MHz. The B122 signals, external clock frequencies, a corrected 1 pps, and parallel BCD code are supplied to the rest of the system through a DATUM Alarm and Transfer Unit (ATU).

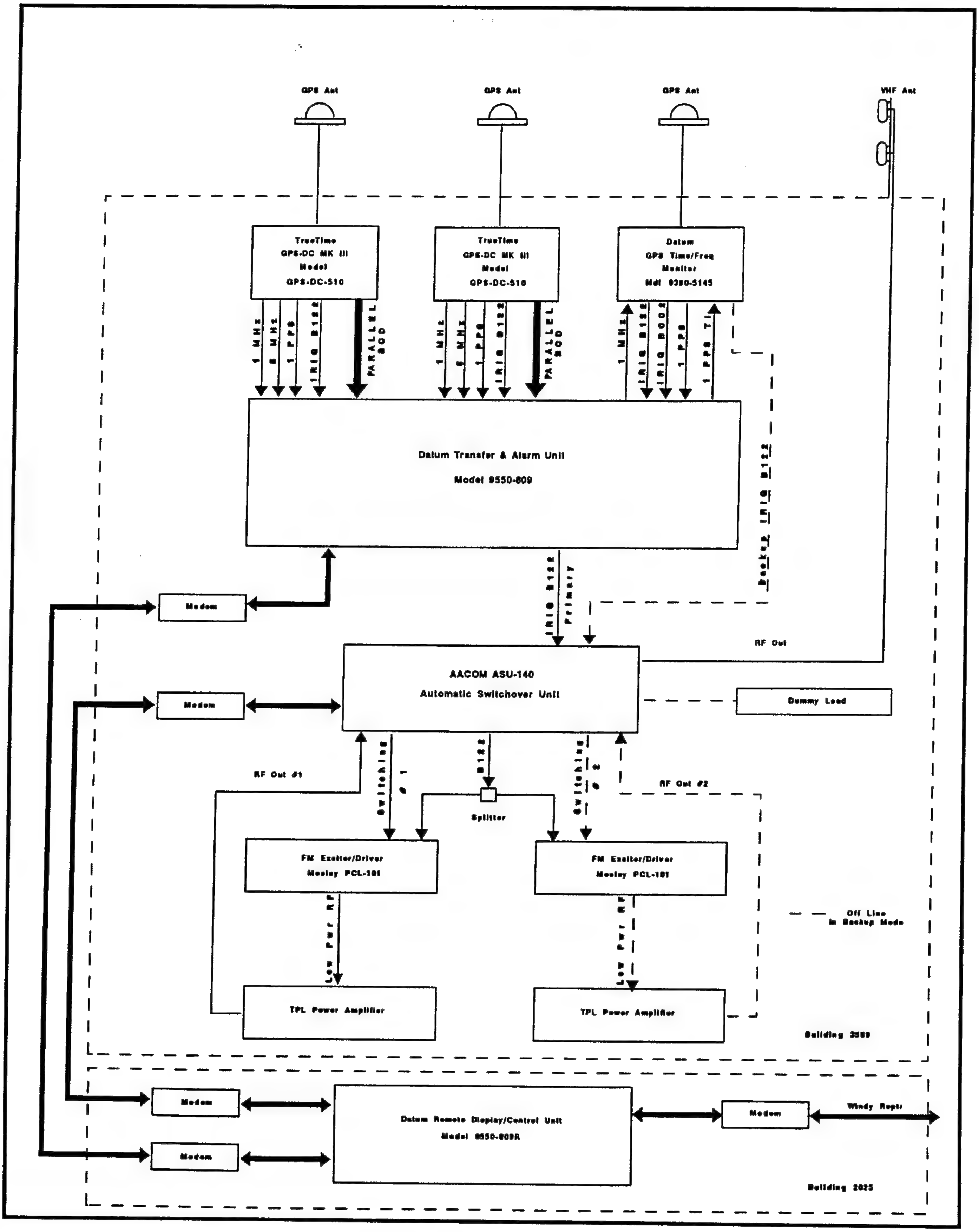



Figure 13. Master Range Timing Station.

GPS Time/Frequency Monitor. A DATUM model 9390-5145 GPS time/frequency monitor is a third source of IRIG B122, corrected 1 pps to the timing system through the ATU. Also provided is an IRIG B002 signal which was used to set the IRIG time bits on start up of the old DATUM time code generators (TCGs). The monitor requires a 1 MHz frequency for operation which is supplied from the on-line MK III through the ATU. Also a 1 pps signal can be inserted to the monitor for time interval measurement to an accuracy of 1 ns.

Alarm and Transfer Unit. The DATUM model 9550-809 ATU is designed to serve as a "traffic center" for the interfacing and control of subsystem timing equipment. Figure 13-1 depicts the various subsystems which interface with this unit. As such, the ATU provides the control, monitoring, and selection circuitry necessary to perform five basic functions. It also contains circuitry to allow control from the Remote Display/Control Panel. The five functions are

(1) Selection of one of two atomic frequency sources for use as the system time base while continuously monitoring the other frequency source for possible use in the event of a failure of the ON-LINE source.

(2) Synchronization of two TCGs with the GPS receiver.

(3) Selection of one of two TCGs as the source of all system outputs while monitoring the other TCG for possible use in the event of a failure in the ON-LINE TCG . The selection is based upon performance characteristics of the 1 pps and IRIG B outputs of both TCGs as compared with the corresponding outputs of the GPS receiver.

(4) Monitoring of the remaining output signals of both TCGs to provide redundancy in the event of a failure of a signal from the on-line TCG.

(5) Monitoring of key characteristics of various other system components to alert users in the event of a fault.

The unit also monitors the remote display/control panel via an RS-232 input line for control signals which will be followed if the unit is placed in the remote control mode. Each detected alarm condition generates an RS-232 status word suitable for driving a printer. In addition, visual and audible indications are provided for each alarm condition.

ACCOM Automatic Switchover Unit ASU-140. The ASU-140 is a solid state unit designed to interface two range time transmitters and control the input and output to effect a redundant system. The unit consists of a logic assembly, a deviation receiver, and an RF switch. The ASU-140 is designed to switch a backup transmitter to the transmit antenna whenever the output of the on-line transmitter

falls to half power or whenever its deviation falls below a selected level. It monitors two incoming IRIG B source lines and switches the output modulation line from the prime source when the input voltage falls below a selected level. Manual control of the off-line transmitter is available for maintenance without affecting the on-line transmitter. The RF output from the off-line transmitter is routed through the ASU-140 to a dummy load when turned on for purposes of performing maintenance. The ASU-140 unit also has the capability of selecting the transmitter to be used and reporting its status to the DATUM remote display/control panel via an RS-232 link. Figure 13-1 depicts the interfacing of the ASU-140 unit to the timing station.

Mosely Model PCL-101 Transmitter. Two Mosely PCL-101 FM transmitters provide the drive power for the transmission of time throughout YPG ranges. These transmitters constitute half of the timing distribution system. The ASU-140 selects one of the two PCL-101s to be the on-line transmitter while the other transmitter is kept in a backup mode. The IRIG B is provided by the ASU-140 to modulate the transmitter. The RF output power is 10 to 12 watts and is used to drive a power amplifier.

TPL Power Amplifier. The TPL Model PA3-1FG-HMS power amplifier receives an RF input signal from the PCL-101 transmitter and amplifies the signal to an RF output of 250 watts continuous duty. The RF signal is then provided to the transmit antenna via the ASU-140 switchover unit.

VHF Antenna. The main transmission antenna, mounted on top of a 150-foot tower, is a series of 8 folded dipole elements stacked to provide an omnidirectional 10-db gain system

Field Receivers. The other half of the distribution system is comprised of VHF FM field receivers. These receivers are commercial FM receiver modules which have been modified and interfaced with external circuitry designed by YPG personnel to provide various timing signals required by the user. Depending on the installation requirement, antennas in use in the field vary from 5/8 wave whips to 9-db gain Yagi antennas.

Remote Display/Control Unit. The DATUM model 9550-809R Remote Display/Control Unit is located in the main electronic building several miles from the timing station building. It is designed to operate with the ATU described previously via an RS-232 link. This unit serves as a remote display of the ATU's front panel system status indicators and its switch position indicators using LED indicators. It buffers the GPS data and the system status message and outputs it to an RS-232 printer.

The unit may also be used to control the same functions as the ATU when control is switched from the ATU to the remote display/control panel. Full monitoring of the ATU status is provided to the remote display/control panel whether or not it has control.

The remote display/control panel has the capability of receiving and displaying the status of two remote ACCOM ASU-140, Automatic Switchover Units (ASUs) and has the capability of selecting the transmitter to be used by each when the ASUs are in the remote mode. The status and control of the ASU-140s is accomplished via RS-232 full duplex links to each.

Windy Mountain Repeater. The Windy Mountain repeater is a quasi range timing station which transmit timing signals to the eastern Kofa firing range. The following paragraphs describe station equipment, and figure 13-2 provides a block diagram of the equipment interfacing.

Timing Source. Two rack mounted VHF FM field receivers provide analog IRIG B timing signals. These signals are derived from the master station range time and are passed to two DATUM TCGs.

Time Code Generators. Two DATUM model 900 TCGs are used to regenerate the IRIG B time code to modulate two transmitters. The TCGs are capable of synchronizing to the incoming IRIG signals from the receivers and providing a means to adjust for propagation delay, so the regenerated IRIG B signal used for transmission is on time in relation to the master range time clock. In the event of loss of a received signal, the TCGs will continue to provide IRIG signals based on the internal oscillator clock. Timing stability can be maintained to 10E-6 in this condition. Upon re-acquisition of a received signal, the TCGs will re-synchronize to the master range time.

Transmitters. Two AACOM model RTT-150A FM transmitters are modulated by the IRIG B signals from the TCGs. These two transmitters provide 10 watts of RF output power to the Switchover Unit.

Automatic Switchover Unit. A second AACOM ASU-140 Automatic Switchover Unit is used to select and control the on-line transmitter. When this unit is in the remote mode, selecting, controlling, and monitoring are accomplished with the Remote Display/Control Unit described previously via full duplex RS-232 link. Regardless of the ASU-140 mode, full monitoring is provided by the Remote Display/Control Unit. The ASU-140 provides an output RF signal to the antenna which is a directional stack of two folded dipole antenna elements.

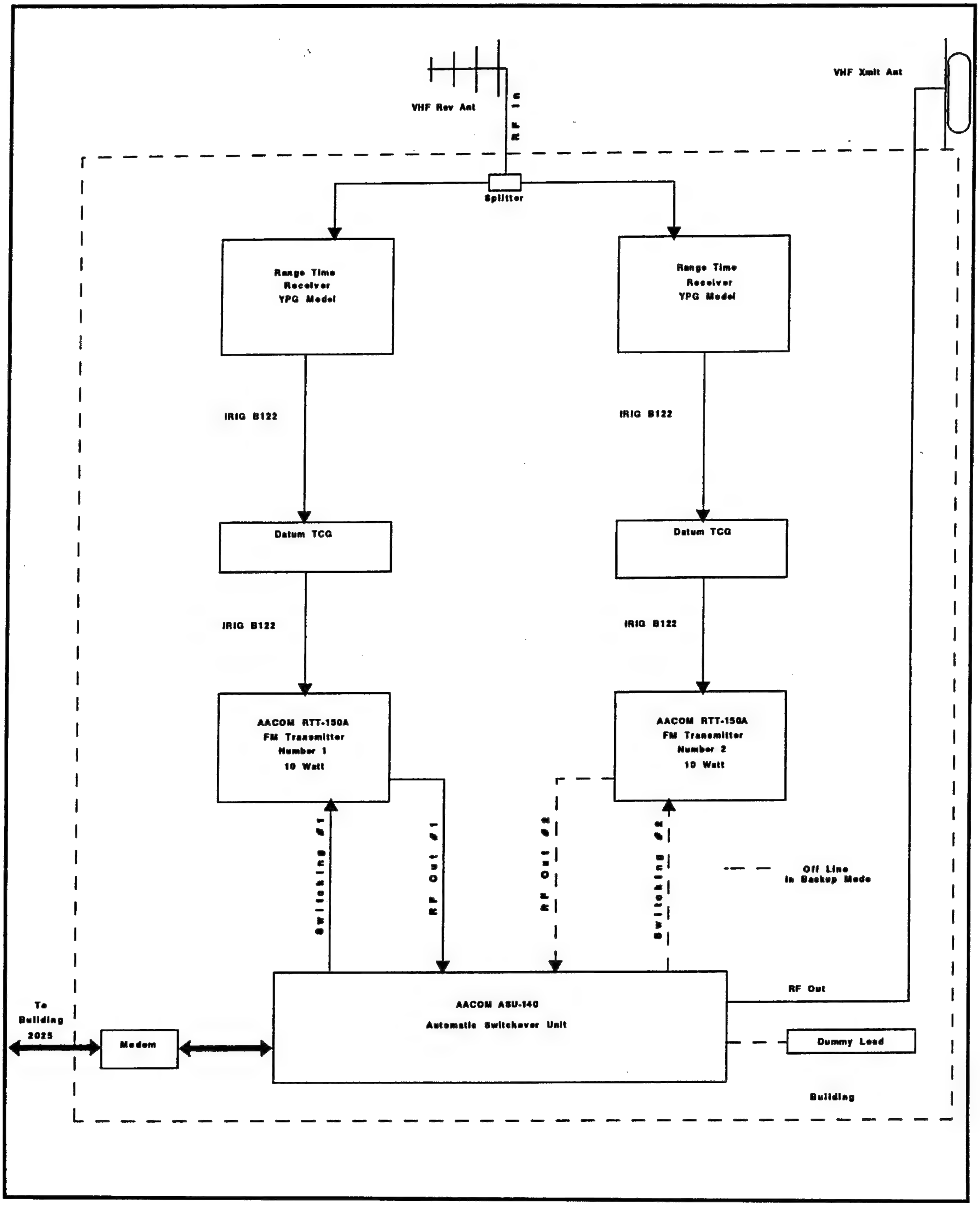



Figure 13-2. Windy Mountain Repeater.

Terminal Equipment. Timing terminal equipment in use at YPG includes synchronized generators and translators from various manufacturers. Locally designed and fabricated LED drivers for edge track timing on high-speed instrumentation cameras are in use throughout the YPG ranges. Many of these LED drivers are specifically designed for use in aircraft installations.

## 4.0 NEAR-TERM PLANNED UPGRADES

Plans for range time improvements include replacement of the DATUM GPS frequency/timing monitor and the addition of a dc to ac converter. The converter will allow the transmitters, which are ac powered only, to be run from a dc power source, thus providing continuous distribution of time during ac power outages.

## 5.0 LONG-TERM PLANNED UPGRADES

The current long term project is to replace the 150-foot guyed tower with a self supporting tower.

SECTION 14

# WESTERN RANGE TIMING SYSTEM
# 30TH SPACE WING, VANDENBERG AIR FORCE BASE

## 1.0 INTRODUCTION

The Western Range Timing System is the master driver for the range countdown system and the missile lift-off system and is an integrated part of the range's voice and data recording system. It also serves as the source of time codes and timing references at various remote instrumentation sites. The timing system supports various ballistic, space, and aeronautical launch and flight operations on the Western Range.

## 2.0 CAPABILITY

The Western Range uses a model GPS-DC-424 receiver, manufactured by TrueTime Inc., for its timing system. Each GPS receiver is equipped with IRIG A and IRIG B time codes and 1 pps, 100 kHz, 1 MHz, and 5 MHz frequency references. Each GPS receiver can also be installed with proper frequency and time code modules to meet specific requirements at any location. The time code outputs have an amplitude of 3 v $\pm$0.5 vpp. The frequency outputs have amplitude of 3 v $\pm$0.25 vpp and $\pm$1 Hz. The stability of the time codes is within 350 nanoseconds of the USNO Master Clock or better. The GPS receiver frequency accuracy is $1X10^{-10}$ when the GPS constellation is being tracked and locked on. The short-term frequency stability is $1X10^{-12}$ a for period of less than 100 seconds. The long-term frequency stability is $2X10^{-12}$ for a period of greater than 60 days.

## 3.0 TIMING SYSTEM DESCRIPTION

The Western Range Timing System consists of 16 GPS receiver stations with a total of 25 GPS receivers throughout Western Range operational areas including Pillar Point Air Force Station and Wheeler Network Control Center in Hawaii. The Western Range Timing System consists of 10 standard timing stations and dual GPS timing stations.

Standard GPS Timing Station. The standard GPS timing station consists of one GPS receiver. The GPS receiver contains the standard time code and time reference modules. The time codes and timing references are distributed through a local transmission system to the users.

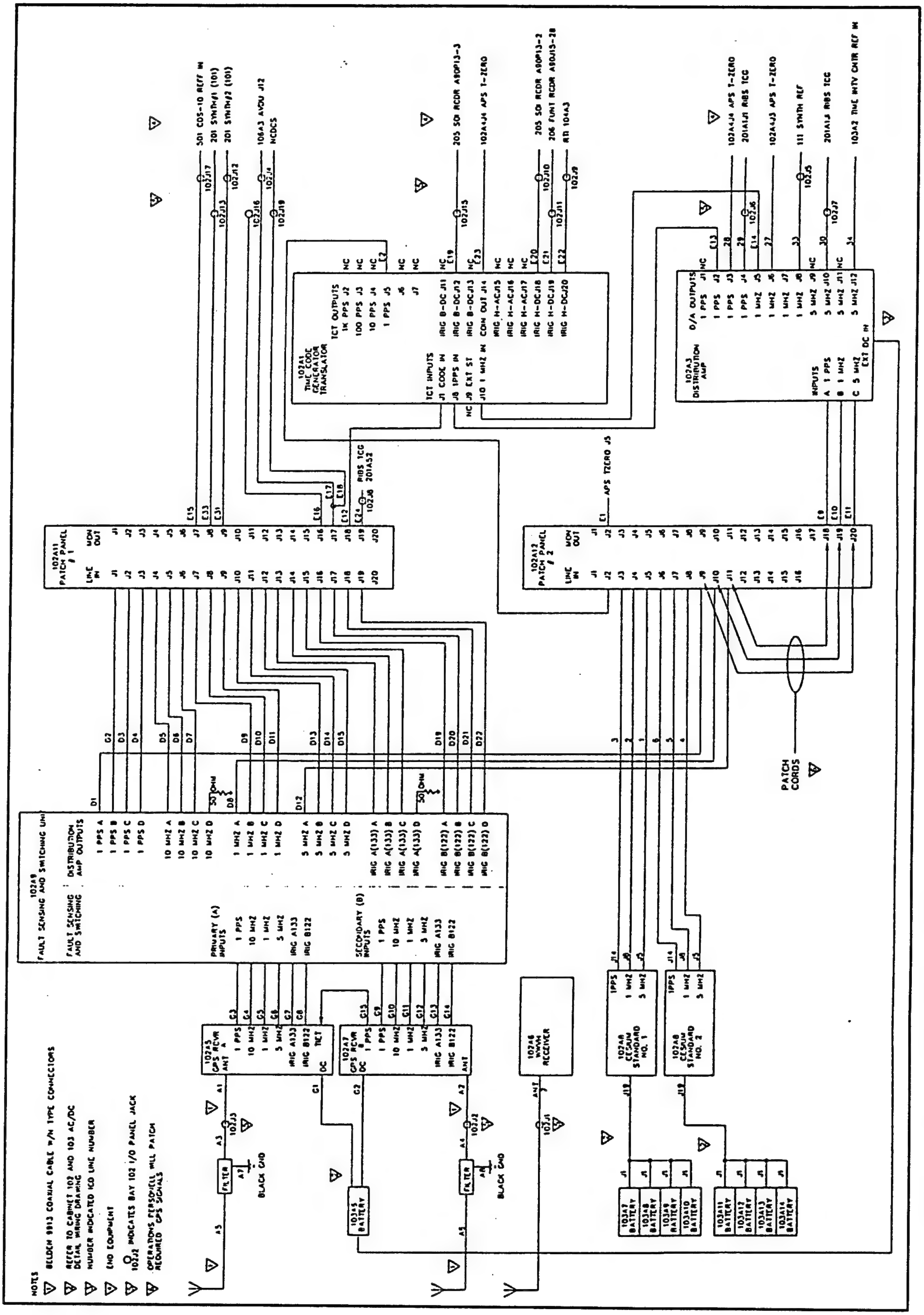



Figure 14-1. Timing system diagram.

Dual GPS Timing Station. Six sites in the Western Range were designated to be dual GPS timing stations because of their geographical locations and mission supporting functions. Each dual station is equipped with two GPS receivers and a TrueTime 560 Fault Sensing and Switching Unit (FSSU). The TrueTime 560 provides both automatic and manual switching from the primary GPS receiver to the secondary receiver when a fault (abnormal voltage level) is detected. The FSSU also provides distribution amplifiers for distributing timing signals and reference frequencies. The basic FSSU consists of a chassis with redundant power supplies, alarms, and monitoring modules (see figure 14-1).

One of the GPS receivers at a dual site is also equipped with the Time Interval and Event Counter (TIET). The TIET module allows a measurement of difference down to ±10 nanoseconds between the 1 pps from the output of GPS to another 1 pps from a second source.

Configuration. All sites not having an Uninterruptible Power Supply (UPS) system had an individual UPS installed for each GPS receiver. The UPS will eliminate the 20-minute warm-up period when the power is restored. None of the GPS receivers at the Western Range are equipped with a selective availability option.

## 4.0 NEAR-TERM PLANNED UPGRADES

Currently there is a project underway to replace the HP discipline oscillator at Western Range HF transmitter and receiver sites; one each located in California and Hawaii. The HP discipline oscillator will be replaced by GPS receivers equipped with appropriate time and timing references for the HF transmitter and receivers.

## 5.0 LONG-TERM PLANNED UPGRADES

Currently a GPS network is being considered for all standard and dual GPS stations in the Vandenberg vicinity. This network will use the existing RS-232 port on the DC-424 unit to link all GPS receivers to a central location. This network will warn operational and maintenance personnel of anomalies in any of the GPS receivers in the field. The network will also allow operational and maintenance personnel to communicate with and command and control the GPS receivers in the field.

## SECTION 15

## EASTERN RANGE TIMING AND SEQUENCING SYSTEMS
## 45TH SPACE WING
## PATRICK AIR FORCE BASE

### 1.0 INTRODUCTION

The 45th Space Wing (45 SW) timing and sequencing systems provide customers on the Eastern Range with a full spectrum of flexible and reliable services. The timing system employs a hierarchy of clocks with the synchronization of each clock traceable to the USNO Master Clock. Cape Canaveral Air Station (CCAS), Antigua, Ascension, and Jonathan Dickinson Missile Tracking Annex (JDMTA) each have station clocks synchronized to the USNO Master Clock. The station clocks provide all IRIG time codes, decade pulse repetition rates, and precision frequencies to users collocated in the same building and distribute synchronizing time signals and frequencies to local site clocks.

The Sequencing System consists of a suite of sequencers that support the various types of launch vehicles. Each sequencer controls the starting and stopping of multiple counts, recycling of the count, autostarting and resetting to initial mission conditions, and setting up of launch windows. In addition, the system provides (1) holdfire controls for use by range safety and other instrumentation control, (2) multiple count distribution and display systems configured to range user requirements, (3) dissemination of first motion time, and (4) remote control functions for various uses.

### 2.0 CAPABILITIES

Timing System

Timing Signals:

| | |
|---|---|
| Code Format: | BCD format defined in IRIG Document 200-95 |
| Repetition Rates: | 1 to 100,000 p/s in decade steps |
| Primary Frequencies: | 100 kHz, 1 MHz, 5 MHz, 10 MHz |
| Communications Std. Clocking Rates: | 75 Hz, 150 Hz, 1.2 kHz, 2.4 kHz, 4..8 kHz, 9.6 kHz |

Time Accuracy (referenced to USNO Master Clock):

| | |
|---|---|
| Range Clock: | 100 nanoseconds |
| Station Clock: | 150 nanoseconds |
| Site Clock: | ±1 microsecond |

Frequency Accuracy:

$10^{-13}$ frequency syntonization to the USNO Master Clock with 2 sigma confidence

Frequency Stability:

| Averaging period (seconds) | Frequency Stability |
|---|---|
| $10^{-3}$ | $8.2 \times 10^{-10}$ |
| $10^{-2}$ | $1.5 \times 10^{-10}$ |
| $10^{0}$ | $5 \times 10^{-12}$ |
| $10^{1}$ | $2.7 \times 10^{-12}$ |
| $10^{2}$ | $8.5 \times 10^{-13}$ |
| $10^{3}$ | $2.7 \times 10^{-13}$ |
| $10^{4}$ | $8.5 \times 10^{-14}$ |

Availability

99.995 percent

Sequencing System

Count Signal Outputs: one

Function Outputs: 128 TTL-to-differential line driver outputs providing relay closures (contact closures of +28 Vdc or -48 Vdc) or optoisolated turn-on (20 mA max Ic @ +28 Vdc)

First Motion Outputs: 1 to 4 +28 Vdc or -48 Vdc current limited outputs

First Motion Inputs: 1 to 4 optoisolated, current limited, reverse-bias protected inputs

Holdfire Inputs: 32 holdfire optoisolated, reverse-bias protected inputs

Range Ready Output: 28 Vdc

## 3.0 SYSTEM DESCRIPTIONS

Timing System. The existing 45 SW Timing System employs a hierarchical system of clocks, each synchronized to the USNO Master Clock. The range clock, which also serves as the station clock for CCAS, is synchronized to the USNO Master Clock.

The CCAS, Antigua, Ascension, and JDMTA each have station clocks synchronized to the USNO Master Clock through the range clock. The station clock provides all IRIG time codes, decade pulse repetition rates, and precision frequencies to users collocated in the same building, and distributes synchronizing time signals to local site clocks. Figure 15-1 is a diagram of ER clock hierarchy.

The range clock is made up of the following components:

| Component | Number |
|---|---|
| Cesium Beam Frequency Standards | 4 |
| Microphase Steppers | 3 |
| Digital Clocks | 3 |
| Loran-C Receivers | 2 |
| GPS Receivers | 2 |
| USNO Monitor System | 1 |
| PTTI Monitor and Control System | 1 |
| Time Signal Generation and Distribution System (triplicated) | 1 |

The range clock is designed to maintain better than ±100 nanosecond synchronization and $10^{-13}$ frequency syntonization to the USNO Master Clock with 2 sigma confidence. The range clock uses synchronization from multiple sources (GPS, LORAN-C, portable clocks, USNO Monitor System) and characterization of the Cesium Beam Frequency Standards to maintain a reliable time scale that can distinguish time and frequency errors from outside sources and the internal Cesium Beam Frequency Standards. Figure 15-2 is a diagram of range, station, and site clock configurations.

Station clocks are located at Antigua, Ascension, and JDMTA and consist of

| Component | Number |
|---|---|
| Cesium Beam Frequency Standards | 3 |
| Microphase Steppers | 3 |
| Digital Clocks | 3 |
| LORAN-C Receivers | 1 |
| GPS Receivers | 1 |
| Time Signal Generation and Distribution System (triplicated) | 1 |

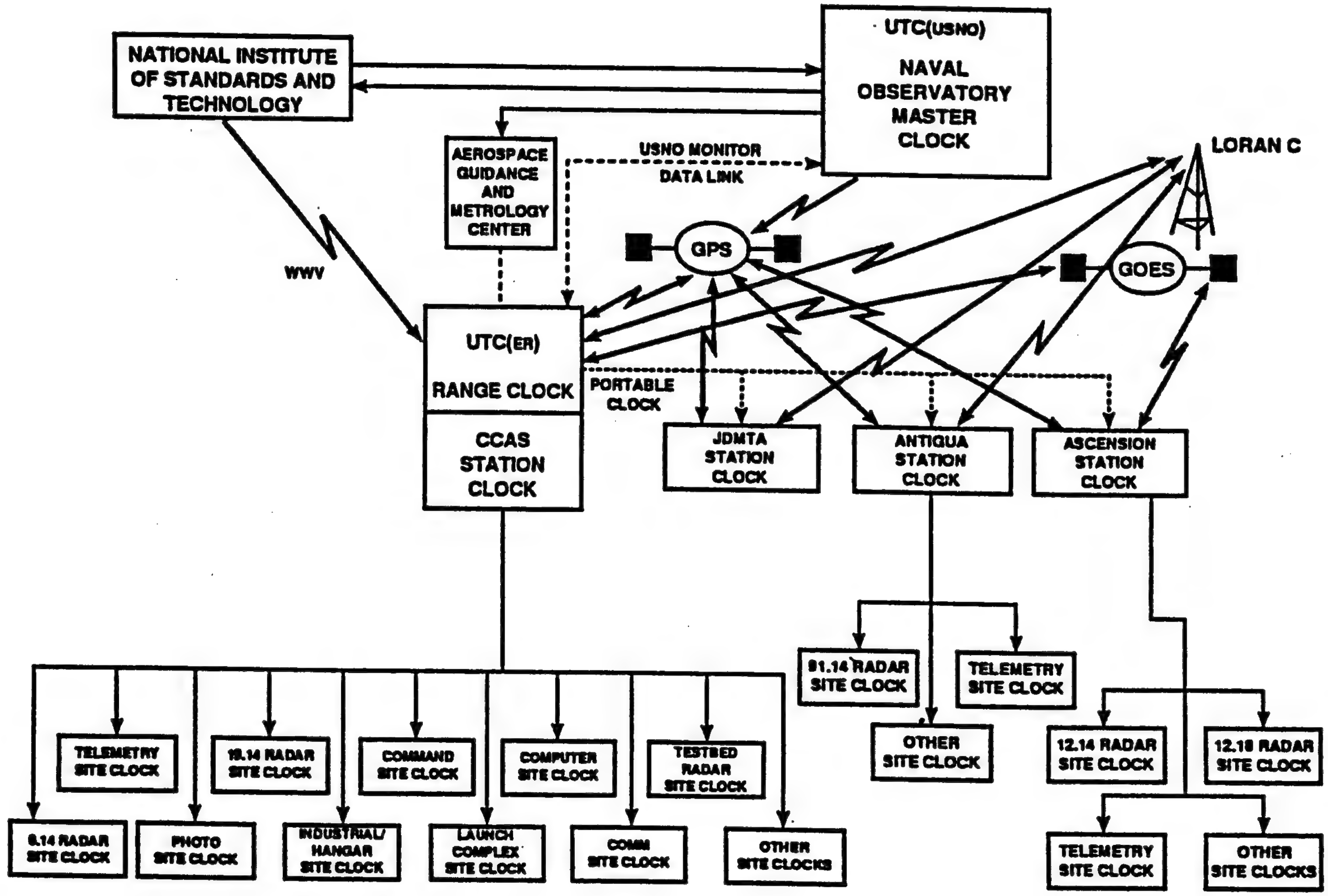



Figure 15-1. Eastern Range clock hierarchy.

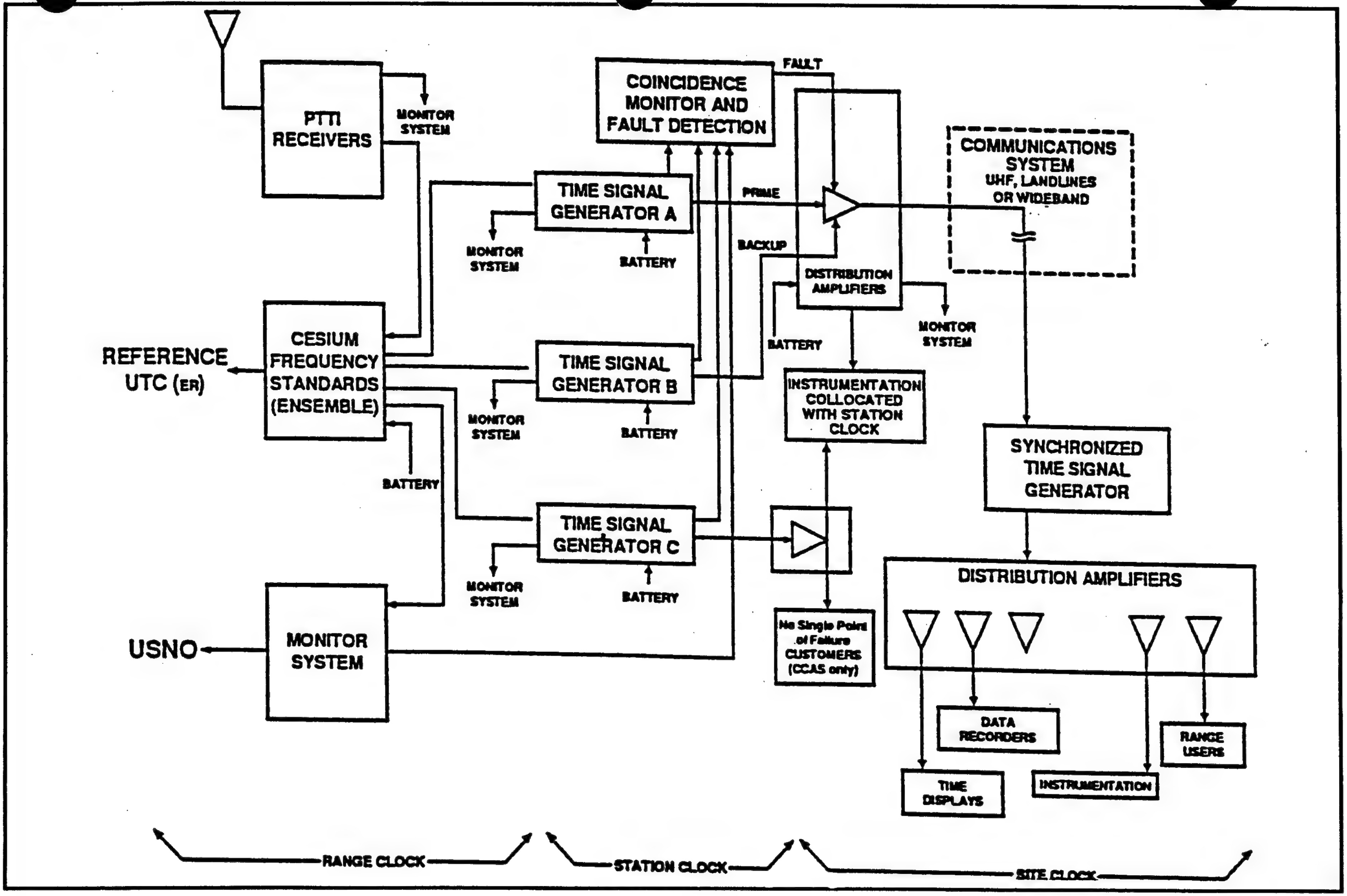



Figure 15-2. Range, station, and site clocks configuration.

These station clocks perform similarly to the range clock and maintain ±150 nanosecond synchronization to the USNO Master Clock with one sigma confidence.

Site clocks provide timing requirements for local instrumentation sites. These clocks are synchronized to the local station clock and provide all IRIG time codes, decade pulse repetitive rate, and frequencies required by the instrumentation sites. The primary synchronizing signal for major instrumentation located at CCAS is transmitted by UHF Radio. The IRIG B120 is provided by landline as backup to the UHF system and is the only signal provided to many site clocks. Each site clock employs a delay compensating synchronized time signal generator to generate all required timing signals "on time." The site clocks are synchronized to the local station clock at better than 1 microsecond.

Sequencing System. The Model V sequencer is part of the sequencing system. The sequencer is designed to operate in conjunction with a Superintendent of Range (SRO) panel or central workstation (CWS). The sequencer controls the starting and stopping of the count, recycling, autostarting, resetting to the initial mission condition, and setting up of the launch window. The sequencer can also be programmed for hold or function outputs and can generate holdfires. The sequencer system (see figure 15-3) includes

| Equipment | Number |
|---|---|
| Sequencer | 12 |
| SRO control panels | 6 |
| Data switch | 1 |
| Range count distribution nets | 4 |
| First motion distribution nets | 4 |

The sequencer consists of two racks of equipment. The first rack includes

Time code reader display
Sequencer cassette drive
Sequencer status display
Sequencer programming and control panel
Card cage
First motion repeat
Printer
Logic power supply
Blower and power supply

The second rack contains

Range ready control
Sequencer junction box
Sequencer output configuration interface
Interface power supply
Blower and power panel

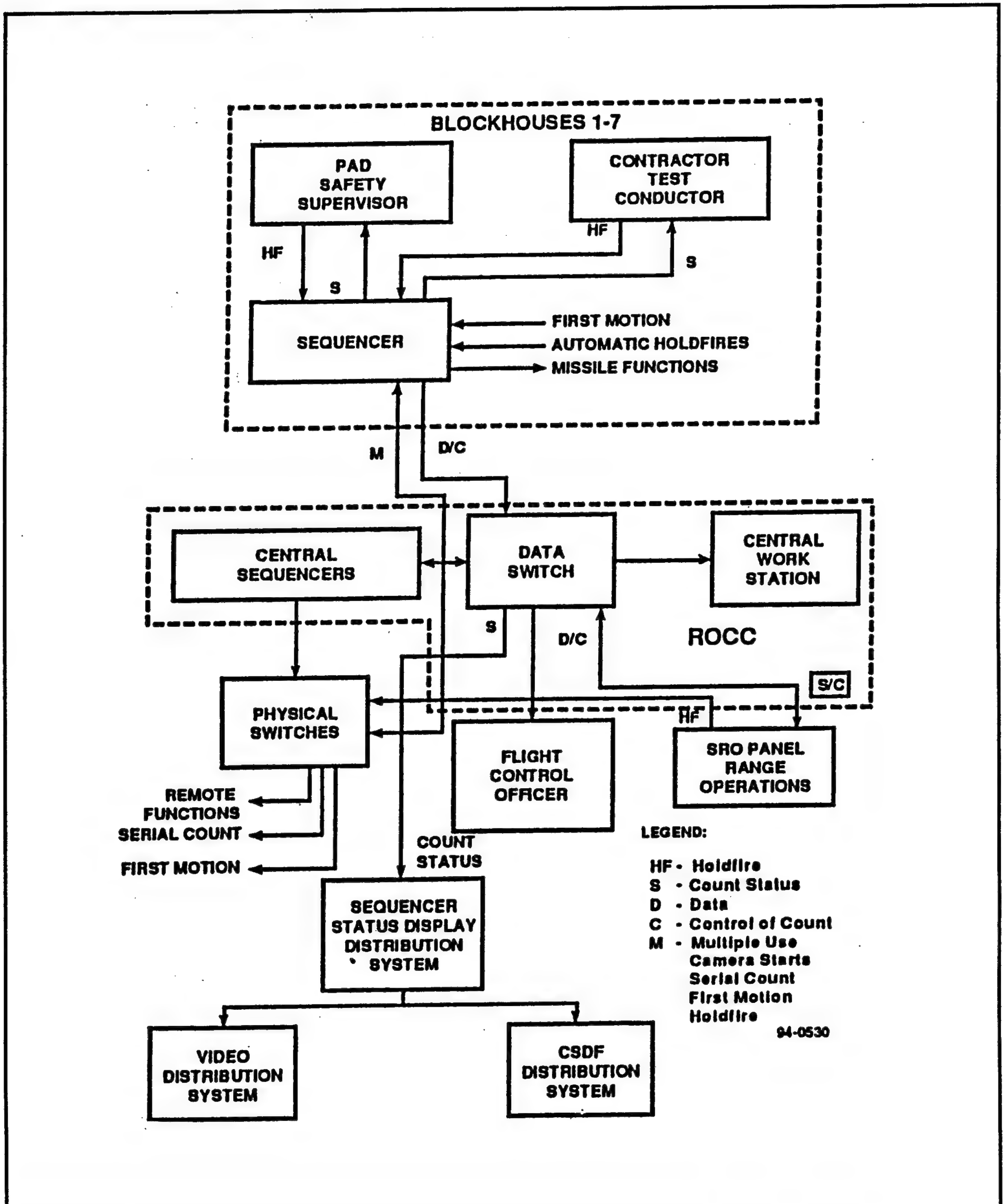



Figure 15-3. Count sequencing system overview.

The Model V sequencer is based on the 8-bit MC6809 microprocessor synchronized to the range timing system. The sequencer generates one minus count and four plus counts. A separate signal is generated for vehicles identified as W, X, Y, or Z. Four first motion (liftoff) inputs are provided. These inputs are continuously monitored by the sequencer and trigger the plus count. The sequencer has the capability for 32 holdfire inputs. These inputs are monitored during individual programmed interval. During the interval, the absence of +28 Vdc on the input will cause a hold.

During an operation, the sequencer located at the blockhouse is the source of the following functions:

On/off sequential control of vehicle and instrumentation
Holdfire controls for count interruption
Count signal distribution for area displays
Distribution of liftoff time
Count status data distribution for video display terminals
Remote control by the range director by way of the SRO panel

The sequencer is pre-programmed with a mission tape. The SRO panel communicates with the sequencer over a bi-directional RS-232 serial data link through the data switch. The data links use 9600 baud modems. The sequencer data presented on the status display is continuously sent via the data link through the data switch and out to various points on the range.

## 4.0 NEAR-TERM PLANNED UPGRADES (1 TO 3 YEARS)

Near-term upgrades of the Timing and Sequencing System include improvements to the sequencers, new pad safety supervisors consoles, and a new L-band timing distribution system. Each Model V sequencer will be augmented with an uninterruptible power supply and upgraded with new CRT displays, printer, and mass storage device. The pad safety consoles are being replaced with a Commercial-Off-the-Shelf (COTS) computer-based graphical display system. The present UHF timing distribution system will be replaced with a new L-band timing distribution system. The system will service multiple receiver sites throughout the mainland Eastern Range.

## 5.0 LONG-TERM PLANNED UPGRADES (BEYOND 3 YEARS)

Long term upgrades to the Eastern Range Timing and Sequencing System are part of the Range Standardization and Automation (RSA) program. They include increased accuracies to less than 100 nanoseconds referenced to the range clock, incorporation of GPS SA/AS into the Range Timing System, and the introduction of a Remote Status and Control System.

SECTION 16

# FREQUENCY AND TIME SUPPORT FOR NASA SYSTEMS

## 1.0 INTRODUCTION

The National Aeronautics and Space Administration (NASA) has Frequency and Timing Systems at many facilities and centers. This text describes six NASA ground based timing systems currently in use. These ground based systems support scientific experiments and spacecraft tracking for Satellite Laser Ranging (SLR), Network Mission Operations Support (NMOS), Kennedy Space Center (KSC), Very Long Baseline Interferometry (VLBI), the Tracking Data Relay Satellite System (TDRSS) Ground Terminal Network, and the Deep Space Network (DSN).

## 2.0 SATELLITE LASER RANGING NETWORK

The NASA Goddard Space Flight Center, under the NASA Space Geodesy Program, coordinates operations and technology for 43 satellite laser ranging stations in more than 30 countries. Within this network, the NASA SLR Network consists of four fixed and four transportable systems. These systems measure distances to Earth satellites which provides precise satellite orbit determination and contributes to several areas of Earth Science.

The accuracy of laser ranging is critically dependent on the proper operation of a stable reference oscillator at each network station. Figure 16-1 is a block diagram of the timing system for a typical laser ranging system, employing a Hewlett Packard standard 5061 Cesium Beam Frequency Standard as the frequency source for the ranging time interval counter. Figures 16-2 and 16-3 show current performance specifications for the frequency standard. To correlate measurements performed at the different stations, ranging data from each station is synchronized to UTC (USNO) to within ±1 microsecond using GPS timing receivers.

The station time position data, time steps, and other pertinent timing information is transmitted daily to the AlliedSignal Technical Services Corporation (ATSC) VAX computer system by the SLR communication network. The data are reviewed and analyzed using an automated time position program that performs a least-square analysis and subsequently produces time position information for the stations. The results of the timing data analysis are reported to the Data Operations Group for inclusion in laser data analysis and the data base. This post processing of the time synchronization data resolves the offset to ±0.5 microseconds.

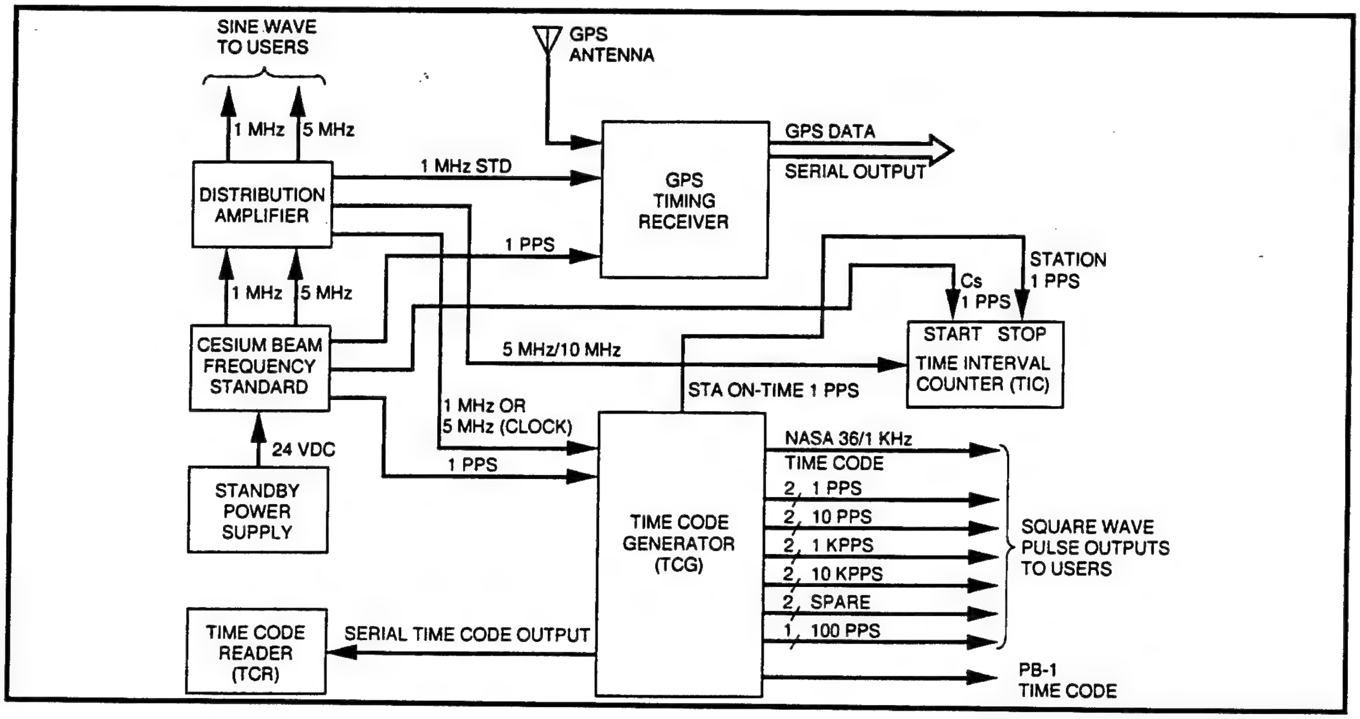



**Figure 16-1. Timing equipment.**

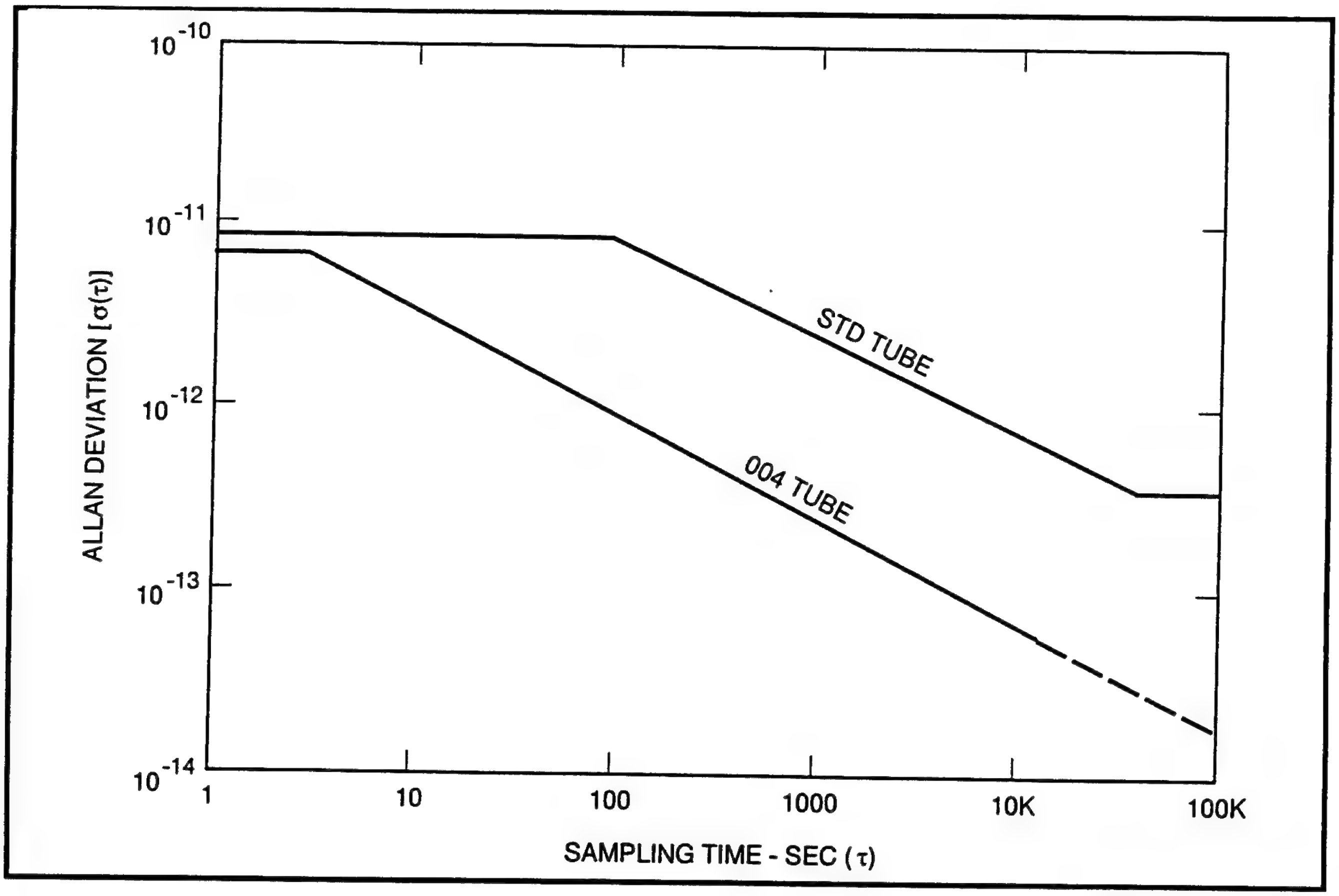



**Figure 16-2. Allan Deviation HP-5061 Cesium Beam Frequency Standard.**

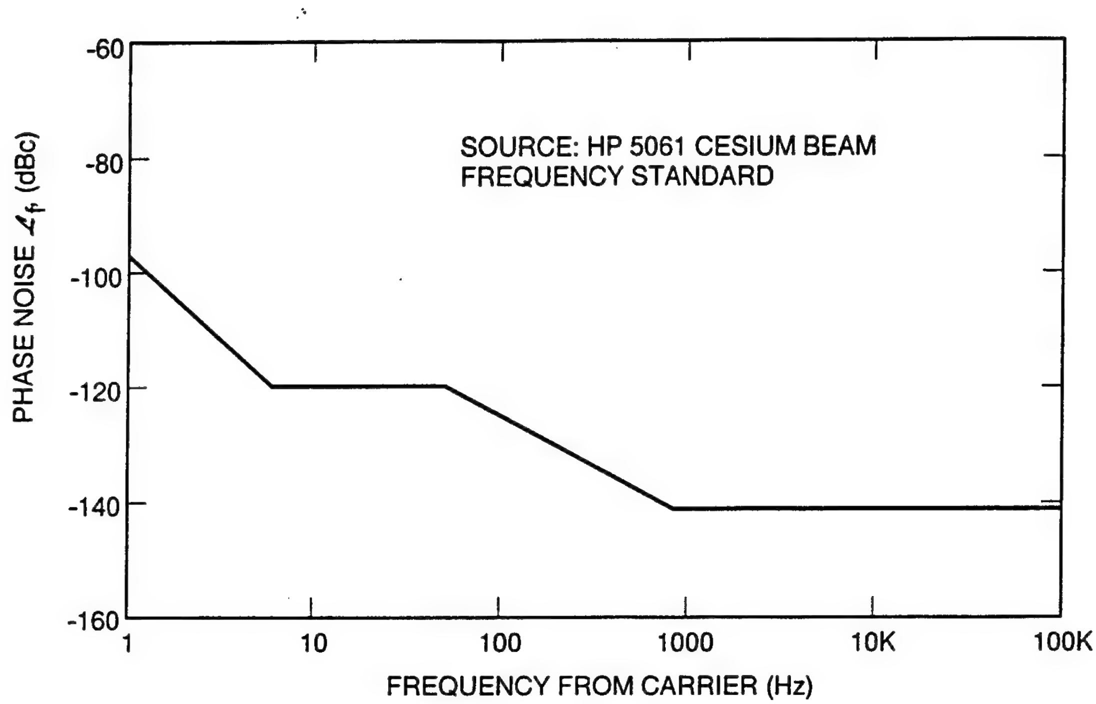



Figure 16-3. Single sideband phase in a 1 Hz bandwidth at 5 MHz.

## 3.0 MISSION OPERATIONS NETWORK

The NASA Goddard Space Flight Center provides pre-launch, launch, and range safety support for the space shuttle and other NASA spacecraft which includes tracking and data collection from low orbiting satellites. Supporting stations are located at the Merritt Island Launch Area (Florida), Ponce De Leon (Florida), Wallops Island (Virginia), and Bermuda. These stations use Hewlett Packard model 5061A and 5061B Cesium Beam Frequency Standards. Frequency stability and phase noise specifications are shown in figures 16-2 and 16-3. Figure 16-4 is a block diagram of the TRAK Systems model 8407 triple redundant clock with majority voting capability which is used at Merritt Island, Wallops Island, and Bermuda. Time offsets of the network's stations are maintained within less than ±10 microseconds from UTC (USNO) using LORAN-C.

## 4.0 VERY LONG BASELINE INTERFEROMETRY

The NASA Goddard Space Flight Center, under the Space Geodesy Program, in coordination with the U. S. Naval Observatory (USNO), the National Oceanic and Atmospheric Administration (NOAA), and agencies of 14 foreign countries, conduct VLBI experiments at 39 stations to measure geodetic baseline vectors of

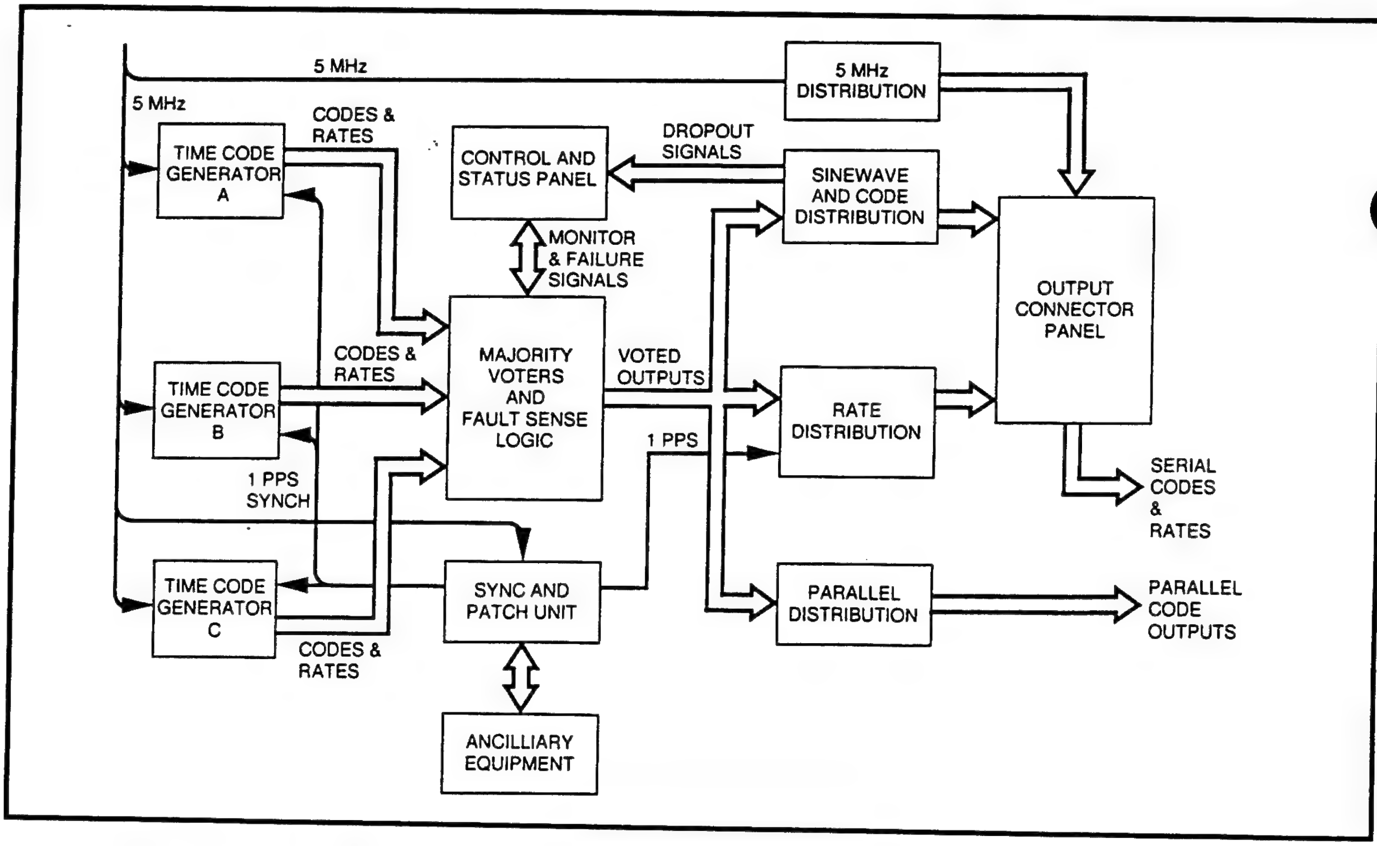



Figure 16-4. TRAK 8407 triple redundant clock.

interest to the Earth Science community. Geodetic VLBI uses radio-astronomy techniques to determine distances on the Earth based on the measured difference in arrival times of quasar radio waves at VLBI stations. Figure 16-5 is a block diagram for a MARK III Data Acquisition System, which is employed by many VLBI stations. At each VLBI station a hydrogen maser provides the frequency reference signal for the local oscillators, for data sampling, for receiver delay calibration, and for the time-of-day clock. The frequency stability (Allan Deviation) of typical VLBI hydrogen masers is 3 times $10^{-15}$ for a sample period of 1000 seconds. The frequency offset of the masers is nominally maintained to less than 5 times $10^{-13}$. Station time offset is typically maintained to within ±13 microseconds from UTC (USNO) to facilitate the correlation of data from the several stations which participate in each VLBI experiment. The GPS timing receivers are used to measure the start and stop times of experiments and to measure long-term frequency offset and frequency drift of the hydrogen masers.

## 3.0 TRACKING DATA RELAY SATELLITE GROUND TERMINAL NETWORK

The NASA Ground Terminal (NGT) located at White Sands, New Mexico, supports the NASA Tracking Data Relay Satellite System. The Second Tracking Ground Terminal (STGT) being constructed (approximately 16 kilometers from NGT) is expected to become operational in 1995

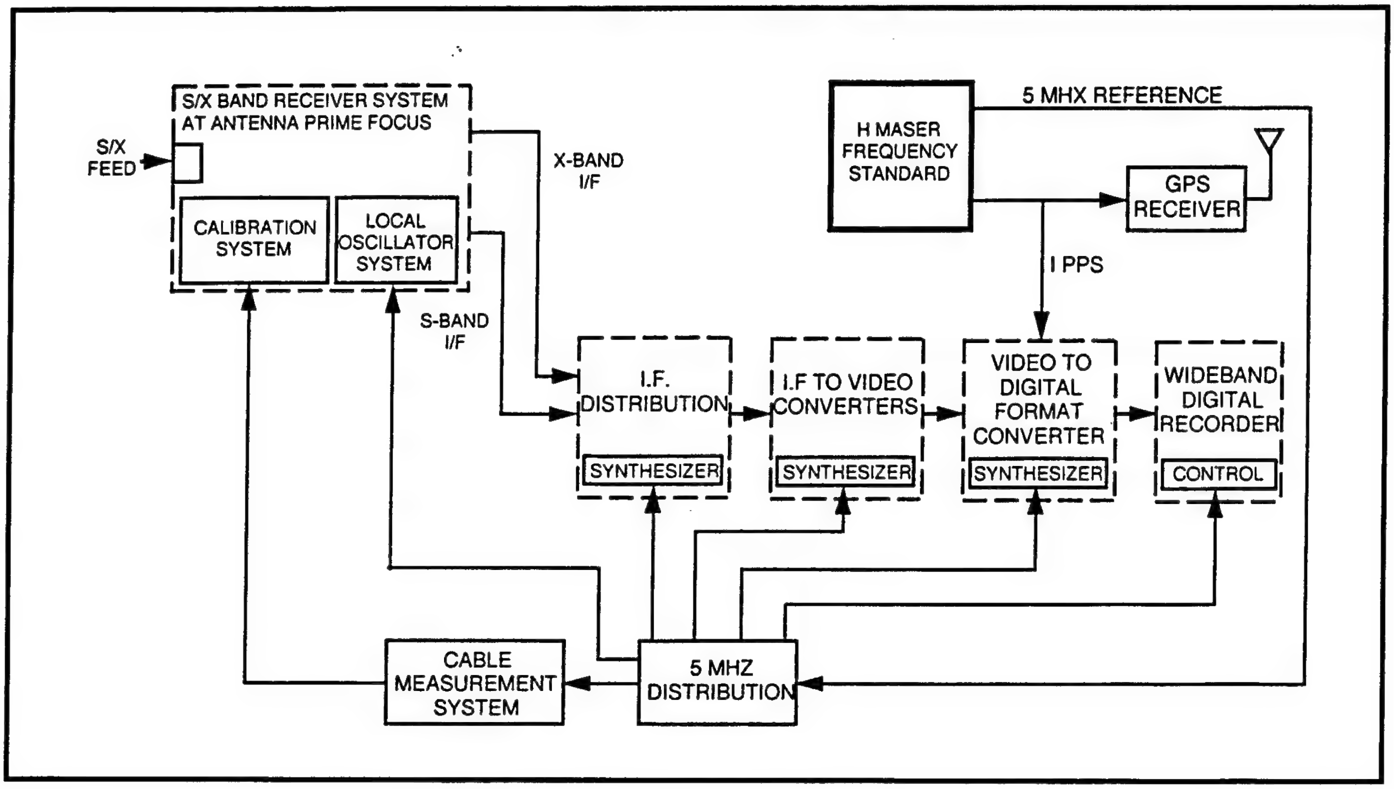



Figure 16-5. Block diagram of the Mark III VLBI Data Acquisition System.

The NGT timing system uses two Hewlett Packard model 5061A-004 Cesium Beam Frequency Standards and automatic nondropout frequency switching equipment. Figure 16-4 is a block diagram of the NGT TRAK Systems model 8407 triple redundant clock which incorporates majority vote capability and distribution of multiple serial and parallel time codes. The GPS timing receivers are used to measure time offset from UTC (USNO). It is planned to upgrade the NGT timing system in 1995 to include a new dual redundant clock and two Hewlett Packard model 5071 High Performance Cesium Beam Standards with each driving a disciplined crystal oscillator to improve phase noise performance. The STGT dual redundant timing system will use two Hewlett Packard model 5061B-004 Cesium Beam Frequency Standards with each driving a disciplined crystal oscillator.

## 6.0 <u>KENNEDY SPACE CENTER</u>

The NASA Kennedy Space Center (KSC) also provides the pre-launch and launch support for the space shuttle and other NASA missions. This launch center has a centralized timing system, which is comprised of two separate clock systems. One clock is dedicated for support of the launch pads, and the second one is for support to the KSC industrial users.

Both of these timing systems are quite similar. The launch pad support timing system is a triple redundant clock with each clock driven by a separate frequency source. One frequency source is a Frequency and Time Systems model 4065 Cesium Beam Frequency Standard. The second source is an Austron model 2100 LORAN-C timing receiver steering an external Austron model 2010B Crystal Oscillator Disciplined Frequency Standard. The third source is an Odetics model 325-868 GPS receiver also steering an internal crystal oscillator disciplined frequency standard. The time from the three time code generators (Odetics model 300-601) are intercompared by monitoring equipment (Odetics model 450). The resultant best clock of the three in the triple redundant set is the centralized complex on-line clock. This timing is then distributed to the KSC launch pads and industrial users.

The Eastern Range timing is available at the KSC timing system through an ER receiver and time code generator. The KSC timing system is shown in figure 16-6.

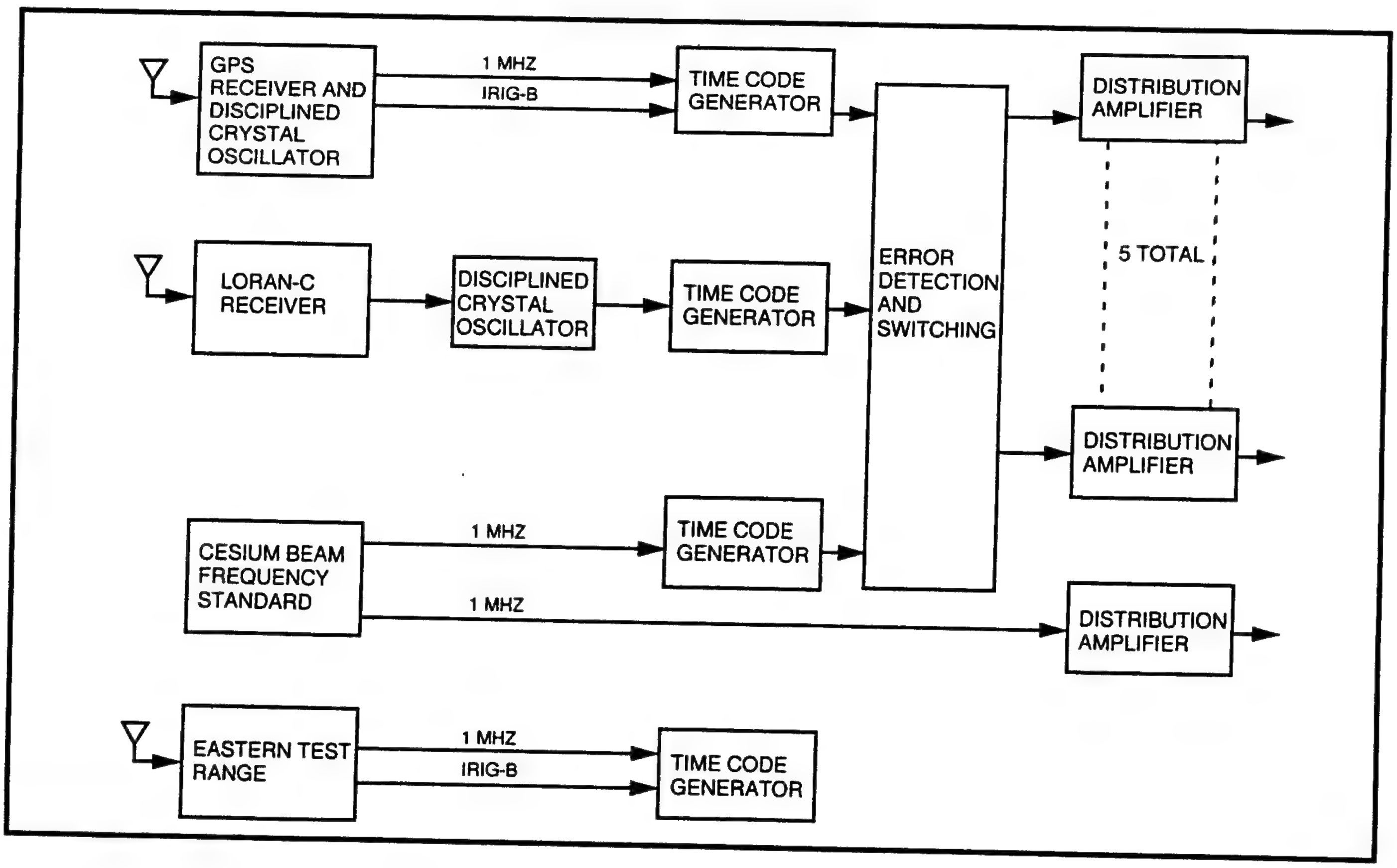



Figure 16-6. Kennedy Space Center Central Timing System.

The time codes available for distribution are IRIG serial codes D through G and NASA 36 bit. Reference frequencies available are 5 MHz and data clock frequencies of 1.544 MHz and 2.048 Mhz.

The requirements for time synchronization are 1 microsecond maximum offset versus UTC (USNO) at the centralized triple redundant clock. There is no requirement for propagation delay correction for timing distribution to the launch pads. The maximum time offset (propagation delay) from the central clock to the launch pads is less than 1 millisecond. The performance specifications for the industrial users are the same.

## 7.0 DEEP SPACE NETWORK

The Jet Propulsion Laboratory (JPL) controls the Deep Space Network (DSN) for NASA including management, engineering, and operation. The three complexes are located at Goldstone, California; Robledo, Spain; and Canberra, Australia. The DSN has provided support for all the deep space probes to the other planets, for example, Magellan's mapping of Venus and Galileo en route to Jupiter. Recently, the DSN has been assigned the additional responsibility for the Earth orbiting station at each of the three complexes.

The Frequency and Timing Subsystem (FTS) at each complex provides support for all missions. Some of the specialized operations are VLBI, radio science, planet mapping, photographs, and other science experiments for all deep space missions.

The Signal Processing Center (SPC) at each complex has two hydrogen maser and two Cesium Beam Frequency Standards. One of the hydrogen masers is the on-line standard with the other as an operating spare. The clock is a TRAK model 8407-2 triple redundant unit with majority voting circuitry. Figure 16-4 is a block diagram of this clock. The reference frequency and timing distribution to users is via coaxial cables within the SPC and fiber optic cables between the SPC and each antenna. Each user is issued a Time Code Translator (TCT) which is, in reality, a synchronized time code generator that is driven by 5 MHz and synchronized by the master clock timing distribution equipment. Adjustable circuitry in each TCT reduces the propagation delay at the users interface to less than 50-nanoseconds offset versus the complex master clock. The block diagram of this frequency and timing system is shown in figure 16-7.

Some reference frequency and timing users are located at antennas which are remotely located from the SPC by 300 meters to 20 kilometers. For most of these antennas, it is necessary to meet the Allan deviation and phase noise performance of the hydrogen maser. The requirements and actual measured performance are shown in figures 16-8 and 16-9. The timing offset between Goldstone, National Institute of Standards and Technology (NIST), and the two complexes in Spain and Australia is 3 microseconds (3 sigma) maximum. Knowledge of this offset, or

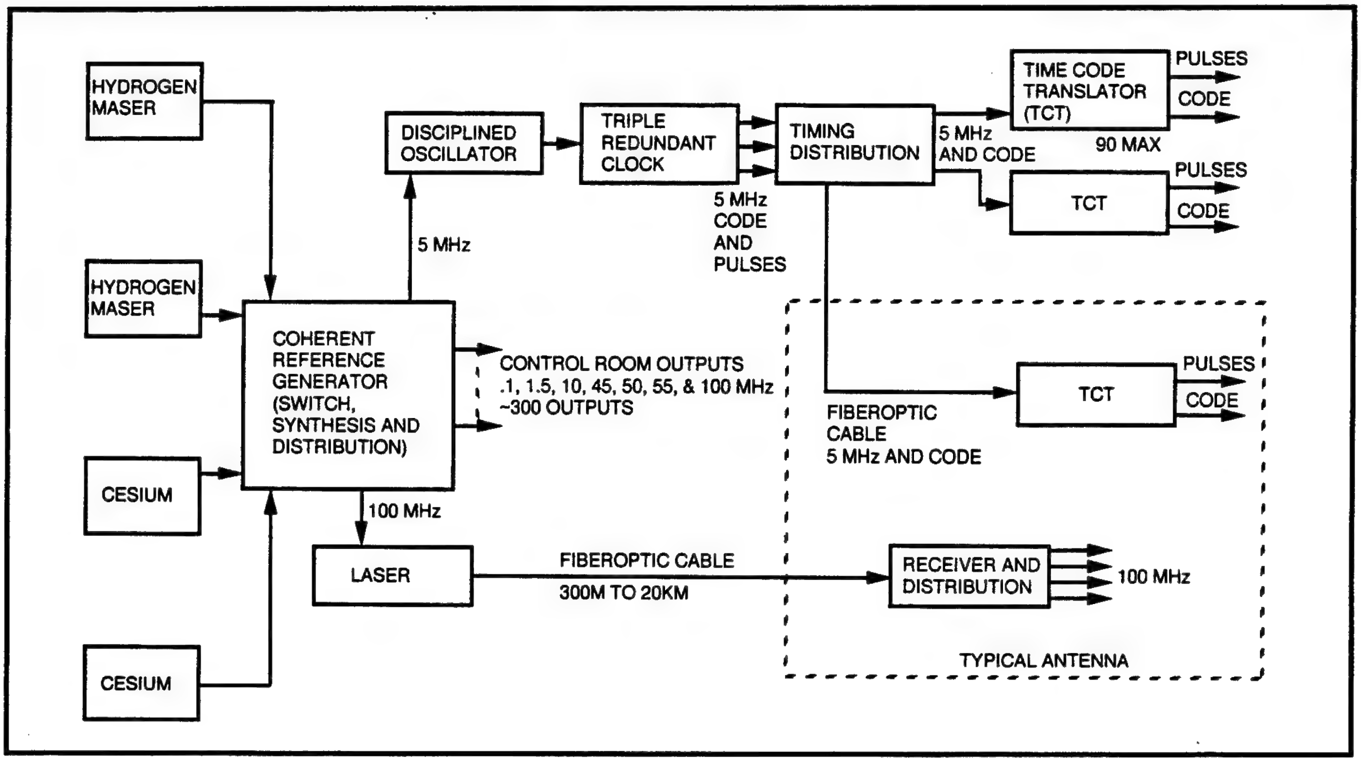



**Figure 16-7. Deep space network complex frequency and timing.**

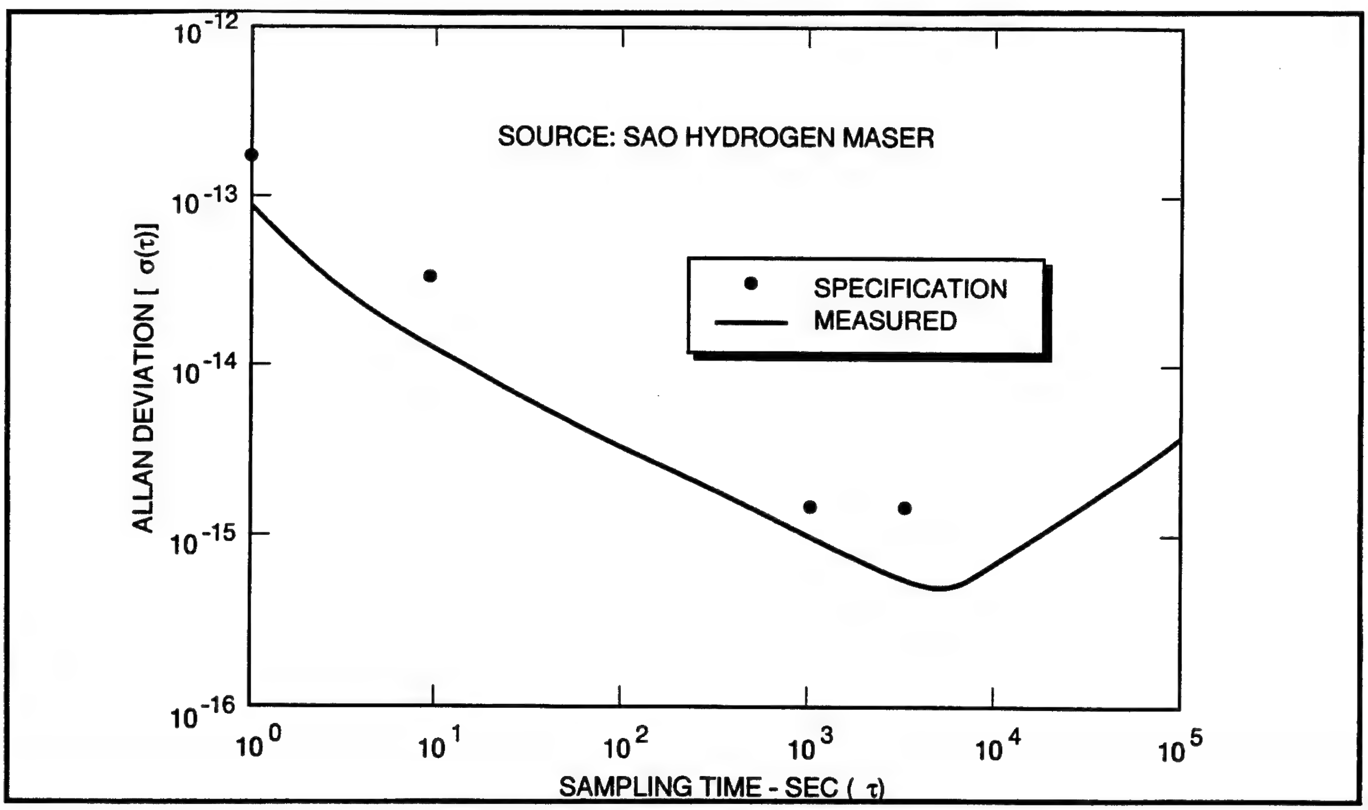



**Figure 16-8. Allan deviation at the antenna**

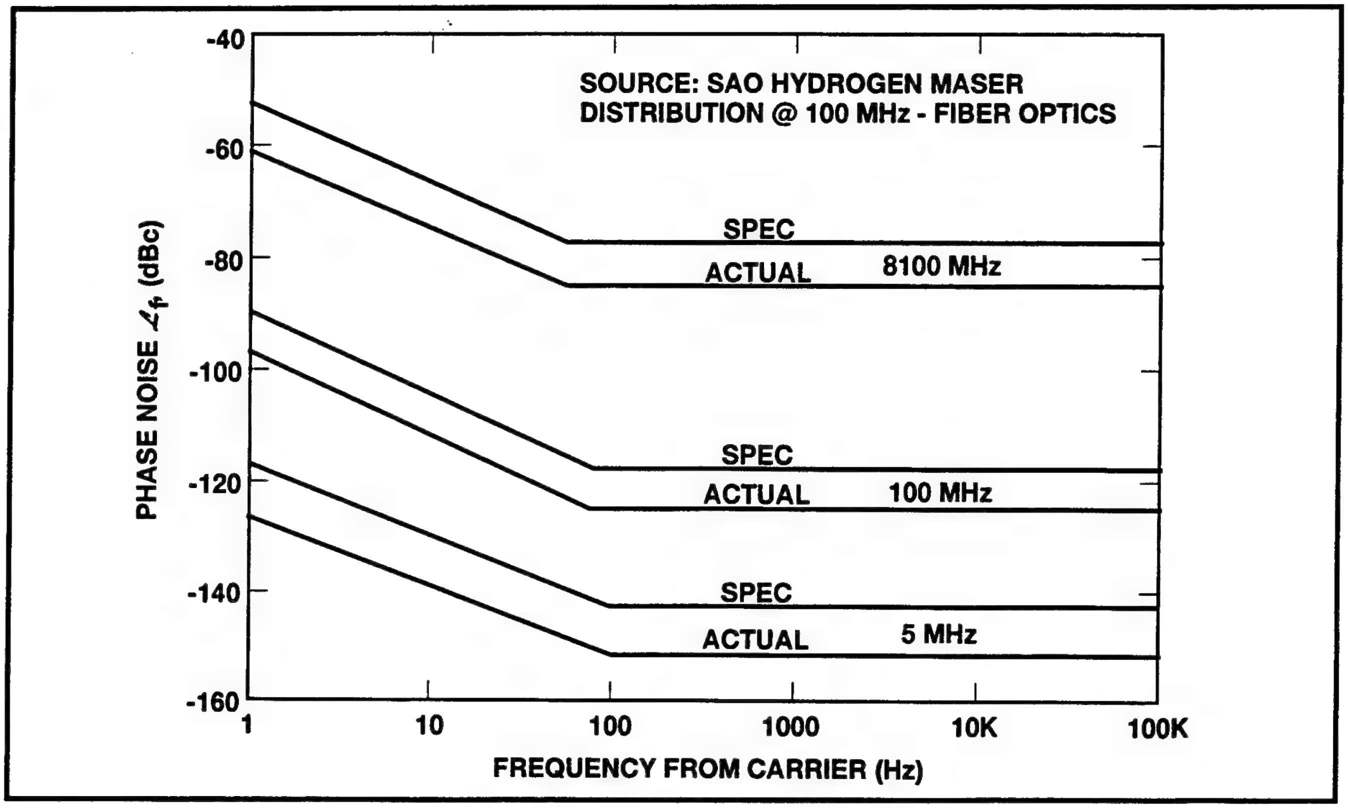



Figure 16-9. Single sideband phase noise at the antenna.

measurement error, must be less than 50 nanoseconds. Frequency syntonization must be less than 6 times $10^{-13}$ (3 sigma) between complexes with knowledge of less than 3 times $10^{-13}$. To guarantee this performance, the measurement must be considerably better.

To guarantee time synchronization and frequency syntonization requirements, GPS receivers employ the common view technique and the current Bureau International des Poids et Measures (BIPM) schedule. Data collected twice weekly from the complex receivers are reduced and published. It is estimated that the worst case frequency and timing measurement error is approximately 1 times $10^{-14}$ and 30 nanoseconds between Goldstone, California, and Australia.

The DSN is currently adding three 34-meter Beam Wave Guide (BWG) antennas at Goldstone and one at Canberra, Australia, plus one 11-meter antenna at each of the three complexes to support the Orbiting Very Long Baseline Interferometry (OVLBI) program.

An FTS distribution is required for each of these new remote antennas which are 16 to 25 kilometers from the SPC. These antennas will be provided with 100-MHz reference frequency distribution that does not degrade the hydrogen maser Allan deviation and phase noise performance via single mode fiber optic.

The cables are 1.5 meters underground to greatly attenuate the diurnal temperature deviations and the resultant 100-MHz phase shift fluctuations. The timing offset will be less than 50 nanoseconds with respect to the complex master clock.

The JPL is currently developing new frequency standards, the Linear Trapped Mercury Ion Frequency Standard (LITS) and the Superconducting Cavity Maser Oscillator (SCMO) Standard, for use in the future. Currently, four LITSs are being built for implementation by the end of 1997. The SCMO short term Allan deviation and phase noise performance has been measured and is much better than anything available today. A combination of LTIS and SCMO would produce short term and long term Allan deviation and phase noise performance which will be required for the Cassini radio science experiment at Saturn.

# SECTION 17

## U.S. ARMY ABERDEEN TEST CENTER

### 1.0 INTRODUCTION

The U.S. Army Aberdeen Test Center (ATC) is a Department of Defense (DOD) Major Range and Test Facility Base (MRTFB). As a general purpose proving ground, ATC has over 250 ranges and firing sites which support automotive and ballistic testing. Instrumentation, in most cases, is brought to the test range and configured to support the requirements of a specific test. By using mobile data acquisition vans and trailers, instrumentation can be provided on-site with real-time data acquisition and reduction at any range or firing site. The ATC fields two types of digital data acquisition vans and trailers: telemetry test site terminals (support automotive testing) and ballistic test site terminals (support firing and live fire testing). These are the ATC assets which employ timing instrumentation. As the systems are different, the timing instrumentation and integration are different.

### 2.0 CAPABILITIES

Telemetry Test Site Terminals (automotive testing): Global Positioning System (GPS) Receivers/Datum Time Code Generators.

| | |
|---|---|
| Code format: | IRIG B |
| Repetition rates: | 1, 10, 100, 1000 pps |
| Time accuracy: | 1 microsecond |
| Frequency accuracy: | 50 nanoseconds |
| Frequency stability: | 5 microseconds |

Ballistic Test Site Terminals (firing/live fire testing): Kinemetrics Satellite Receivers/Datum Time Code Generators.

| | |
|---|---|
| Code format: | IRIG B |
| Repetition rates: | 1, 10, 100, 1000 pps |
| Time accuracy: | 1 microsecond |
| Frequency accuracy: | 50 nanoseconds |
| Frequency stability: | 10 microseconds |

## 3.0 TIMING SYSTEM DESCRIPTIONS

Telemetry Test Site Terminals - see figure 17-1.

Ballistic Test Site Terminals - see figure 17-2

## 4.0 NEAR-TERM PLANNED UPGRADES

Telemetry Test Site Terminals: Acquire additional GPS receivers.

Ballistic Test Site Terminals: Convert to GPS receivers.

## 5.0 LONG-TERM PLANNED UPGRADES

Telemetry Test Site Terminals: None.

Ballistic Test Site Terminals: Evolving requirements for data timing resolutions in nanoseconds will require the market be searched for systems which will accurately provide this capability.

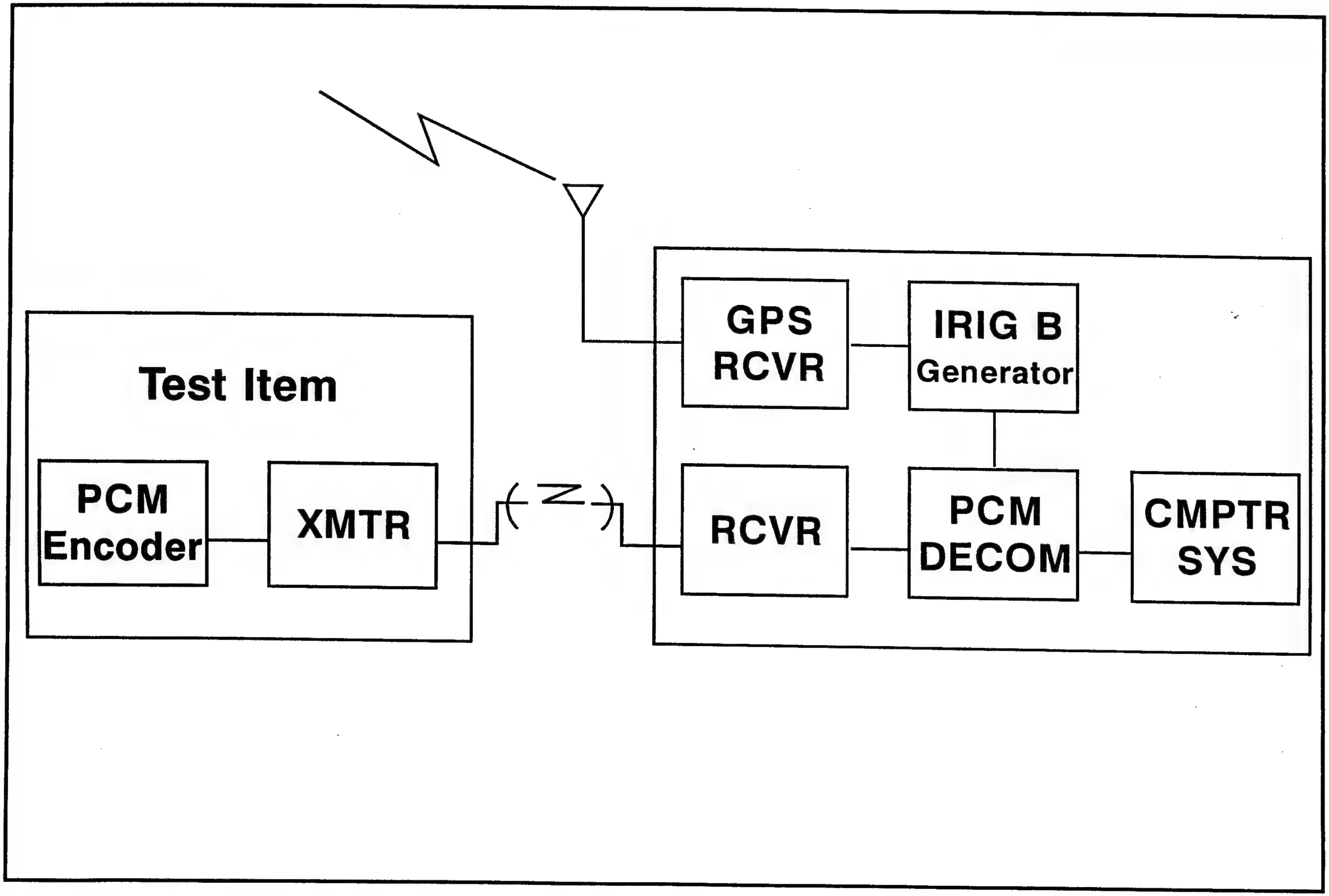



Figure 17-1. Telemetry test site terminals (automotive testing).

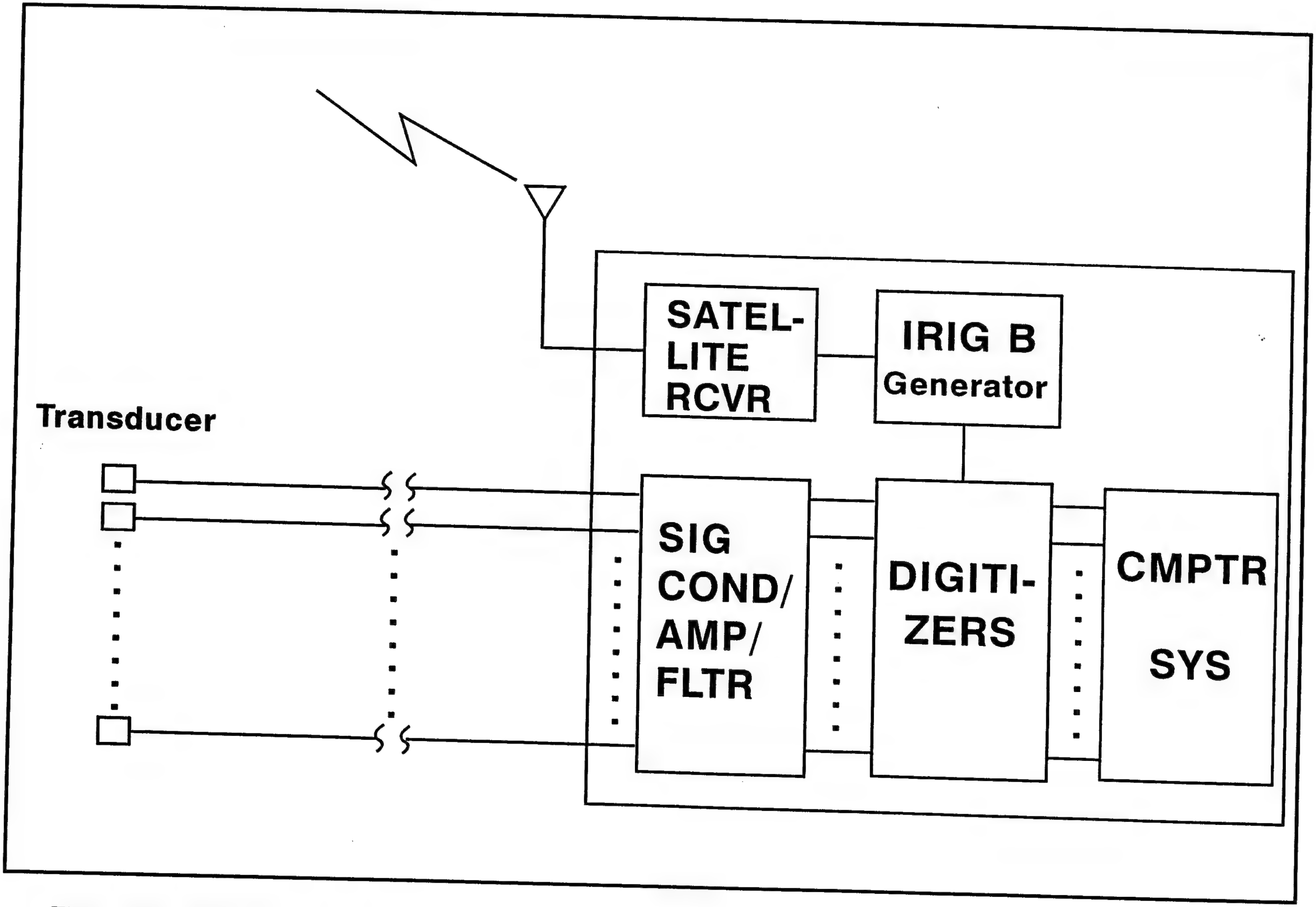



Figure 17-2. Ballistic test site terminals (firing/live fire testing).

## SECTION 18

## ATLANTIC UNDERSEA TEST AND EVALUATION CENTER
## NAVAL UNDERSEA WARFARE CENTER DIVISION NEWPORT

### 1.0 INTRODUCTION

This document provides a basic explanation of the system configuration and operational characteristics of the timing systems at the Atlantic Undersea Test and Evaluation Center (AUTEC) Detachment of the Naval Undersea Warfare Center (NUWC) Division Newport. The AUTEC tracking range is located on Andros Island, Commonwealth of the Bahamas, with headquarters in West Palm Beach, Florida. All timing functions at AUTEC are currently performed by the Communications and Timing Department of the Maintenance and Operation contractor under the cognizance of the Range Systems Branch. Precise time and time marks required by AUTEC are currently provided by two independent systems: the main base or AUTEC Timing System (ATS), and the AUTEC Subcentral Timing Systems (ASTS) located at each remote downrange site.

### 2.0 AUTEC TIMING SYSTEM

The ATS located at the main base is the central timing source at AUTEC and is comprised of two complete and independent timing systems. It feeds two common distribution units through one common Alarm and Transfer Unit (ATU). Refer to figure 18-1 for a system block diagram.

Oscillator. Each of the two systems are disciplined by separate outputs of 5 MHz from FTS Cesium Beam Oscillators Standards. These oscillators replaced the Efratom Rubidium Standards and added accuracy and stability to each system thus requiring a minimum amount of maintenance. Typical accuracy of each standard is $\pm 7\times10^{-12}$ and a stability of $2\times10^{-13}$ per day. With the addition of the two Cesium Beam Oscillator Standards and the procurement of excess items, AUTEC central timing now uses the four portable Rubidium Standards for increased stability in remote or portable timing applications.

Time Code Generator/Synchronizer. Each system contains a model 3180 Time Code Generator (TCG) made by DataChron Inc. of Anaheim, California. These units can be operated in either the generate or synchronized mode. All operating modes, system diagnostics, and settings are entered through a front panel keyboard assembly. A lockout function is included to deny access and to prohibit unauthorized entries. When operating in the generate mode, the unit can be manually synchronized to an

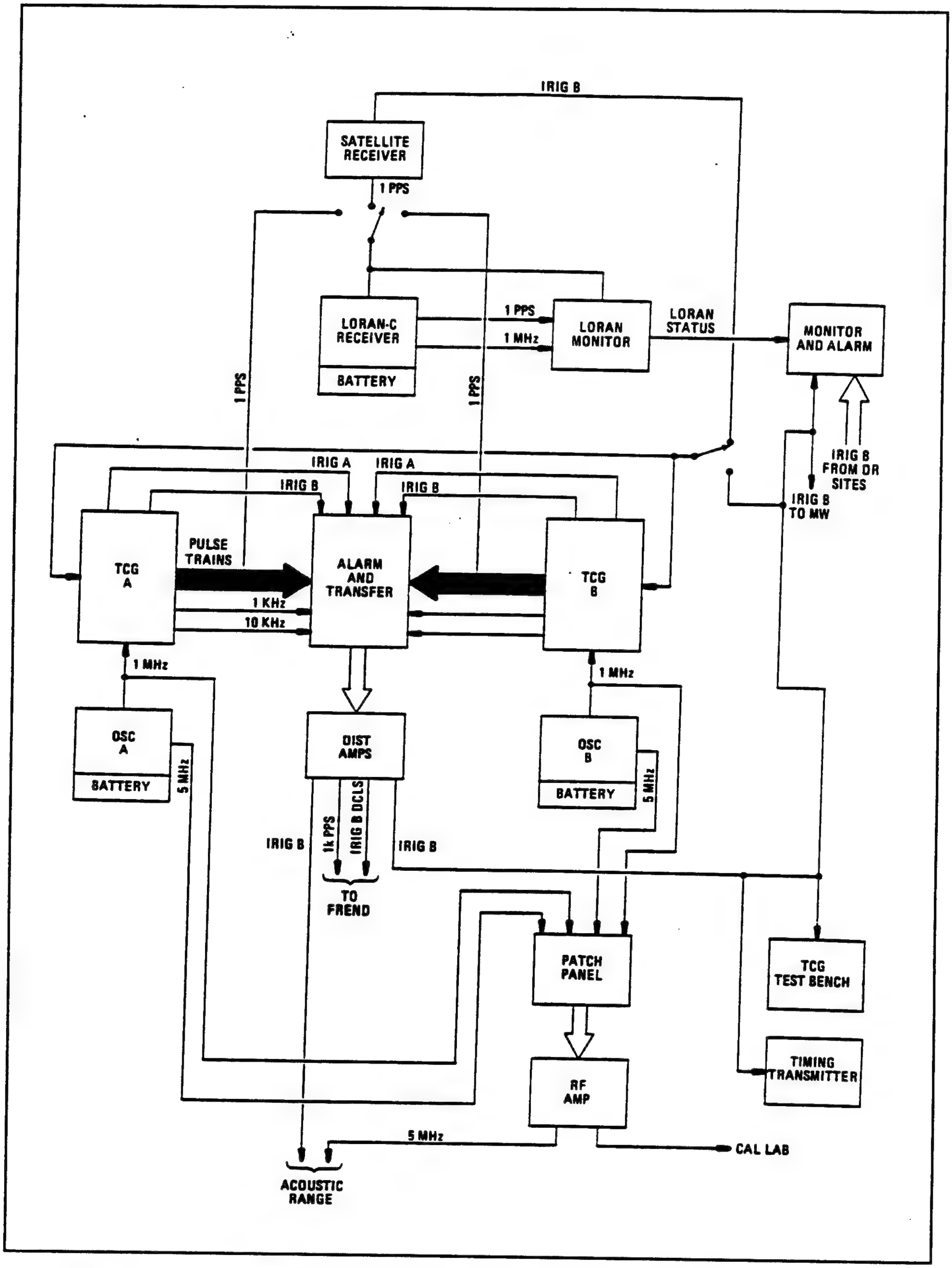



Figure 18-1. AUTEC timing system (main base) block diagram.

external time standard by using the controls mounted on printed circuit boards which are easily accessible from the front via hinged doors. In the synchronized mode, the unit automatically synchronizes to an IRIG $B_{ac}$ input signal with delay compensation programmable via the keyboard. In addition, the model 3180 uses a microprocessor for real-time system monitoring, parameter programming, and self-contained diagnostics.

Digital Display and Decoder. Each system also contains a means of displaying the generated or synchronized time. The real time count is accessed by a 40-bit BCD bus from the TCG. The unit uses 1-inch LED displays showing the days, hours, minutes, and seconds.

Alarm and Transfer Unit. The heart of the ATS is the Alarm and Transfer Unit (ATU). This unit is, in effect, a large solid state switch. It accepts IRIG signals from both TCGs and a third IRIG signal or bit error from one of the two clocks and switches the time code and pulse rate outputs of the alternate clock to the distribution units. Upon detection of a loss of signal or code error from one of the two clocks, a visual and audible alarm is activated which requires operator intervention to be reset. A keyboard entry can then be made to the unit to determine which system was in error and the nature of the error. In addition, the keyboard can be used to measure the time offset between whichever clock is master and another IRIG source (typically the alternate system).

Timing Distribution Unit. The distribution units consist of several ac, dc, and RF amplifier modules operating from plus and minus 15-volt power supplies. The ac amplifiers are primarily used to transmit IRIG ac codes to external equipment whereas the dc amplifiers are used to send both IRIG dc codes and precise pulse repetition signals. The RF amplifiers accept direct inputs from the Cesium Beam Oscillator Standards and drive the signal via a fiber optic link to the Calibration Laboratory where the 1 MHz standard is used to calibrate all test and measurement equipment used at AUTEC. All outputs of the distribution units are balanced line (isolated from the chassis ground) and through Twinax connectors to minimize the effects of RFI.

Error and Detection Unit. This unit continuously monitors the generated IRIG $B_{ac}$ signals from each of the Subcentral Timing Systems located at the downrange sites. The input signals are compared to the IRIG $B_{ac}$ signal generated by the on-line master clock of the ATS. Upon detection of any loss of signal or code error, the unit will set a visual and audible alarm requiring operator intervention for reset. The IRIG signals produced by the downrange sites are transmitted via the AUTEC digital microwave system to the main base (site one).

NAVSTAR Receiver. The ATS currently maintains time with an accuracy greater than 1 microsecond with respect to Coordinated Universal Time (UTC) by means of a Datum model 9390 Global Positioning System (GPS) receiver. The unit is programmed for automatic track of up to four satellites for maximum availability. Precise time synchronization and frequency measurements are achieved with a high

degree of accuracy and reliability. After the timing system synchronizes to UTC from GPS, the timing systems delay offset can be monitored via the GPS receiver. The GPS receiver accepts a 1 pps input from the timing system in which a delay offset is determined. Both timing systems can be set to better than 1 microsecond accuracy of UTC traceable to the United States Naval Observatory (USNO) using this method.

LORAN-C Receiver. The ATS also takes advantage of the close proximity of AUTEC to the LORAN-C slave station at Jupiter, Florida, broadcast to provide a precise time and frequency reference traceable to the USNO as a backup to the NAVSTAR receiver. An Austron model 2100 programmable LORAN-C receiver is used. The receiver automatically finds the correct cycle and code of the incoming 100 kHz carrier signal and locks a 1 pulse per second output to it. This backup system ensures AUTEC's Central Timing System maintains a high degree of accuracy.

## 3.0 PORTABLE TIMING UNITS

The AUTEC project currently has seven Datum model 9150 airborne type portable TCGs, eight AUTEC produced Data Gathering System Synchronizers (DGSS), and four TrueTime model GPS-TMD receivers. These units are primarily used by range users who require time tagged data accumulated onboard sea going vessels or antisubmarine warfare (ASW) aircraft. The AUTEC range user has a variety of choices.

Time Code Generators. The model 9150 TCG is versatile in that it can be synchronized with one of two UHF or one of four VHF IRIG B receivers available at AUTEC. For improved stability, the model 9150 TCG can be disciplined by one of the four Rubidium Oscillator Standards. The internal oscillator is an oven controlled crystal with a stability of $1x10^{-6}$ parts per month. The Rubidium Oscillator Standards provide a typical stability of $1x10^{-11}$ parts per month. These units are built for airborne high dynamic environments and contain a battery backup supply for remote installations without a loss of time. Their outputs include multiple pulse rates, IRIG $B_{ac}$, IRIG $B_{dc}$ and a special pulse rate output to provide synchronous ping underwater tracking signals at AUTEC.

Data Gathering System Synchronizers (DGSS). The eight DGSS in the AUTEC inventory are used for synchronizing fire control systems onboard weapon launch platforms that come to AUTEC for weapons systems performance evaluations. These units are driven by crystal oscillators that have a typical stability of $1x10^{-3}$ per month. The units have internal batteries for remote installation. A DGSS offers few TTL outputs along with a DGSS pulse used for time marking purposes. The units are small and lightweight and get the most use of all AUTEC portable timing units.

GPS Timing Receivers. Four TrueTime GPS-TMD receivers were added to the AUTEC inventory in 1994. These units offer very high accuracy and provide a IRIG B,

1 kHz time code output that is within 1 microsecond of UTC. Other outputs are 1 pps and 1 kpps. These units are small and lightweight and totally automatic during setup.

## 4.0 SUBCENTRAL TIMING SYSTEM

An AUTEC Subcentral Timing System (ASTS) is located at each of the three downrange sites and were installed in 1989. They replaced stand-alone timing systems that used Hyperion TCG/synchronizers manufactured in the 1960s. The new systems improve the accuracy and long-term stability to the data acquired by the downrange sites. Each site is equipped with a single TCG display unit and a timing distribution unit that typically is operated in the synchronize generate mode, synchronizing to the IRIG-$B_{ac}$ signal provided from the main base ATS over the Aydin digital microwave system (see figure 18-1 for a system block diagram). The units automatically switch to generate mode if a loss of input is detected. All systems were manufactured by DataChron.

Oscillator. The ASTS uses the 1 kHz IRIG-$B_{ac}$ carrier from site one as a frequency source and locks the output of a disciplined crystal oscillator to 10 MHz. This output is a long-term stable frequency source to drive the TCG after the latter has been synchronized to the incoming IRIG B time code. The error correction voltage used to disciplined the tuneable oscillator is converted into a digital word and stored in memory. Once per second, this stored value is updated. In the event of a microwave failure or the loss of the incoming IRIG B signal from site one, the oscillator will continue to "flywheel" at the last stored value. When signals are restored, updating automatically resumes.

Time Code Generator Synchronizer. The ASTS TCG are similar to and use much of the same logic circuitry of the ATS TCGs at the main base. The exceptions are a built-in display of time and date information and the disciplined oscillator mentioned earlier. The units are typically operated in the synchronized mode, synchronizing to the IRIG B from the main base. Each unit is programmed with its calculated propagation delay to stay with required timing specifications.

Timing Distribution Unit. These units are identical to the units employed in the ATS at the main base. They consist of multiple ac and dc signal amplifier modules operating from plus and minus 15 volt power supplies. The ac amplifiers are primarily used to transmit IRIG $B_{ac}$ codes to external equipment, whereas the dc amplifiers are used to transmit IRIG dc codes and precise pulse repetition signals to external systems. All outputs are balanced line (isolated from the chassis ground) through Twinax cable and connectors to minimize RFI contamination.

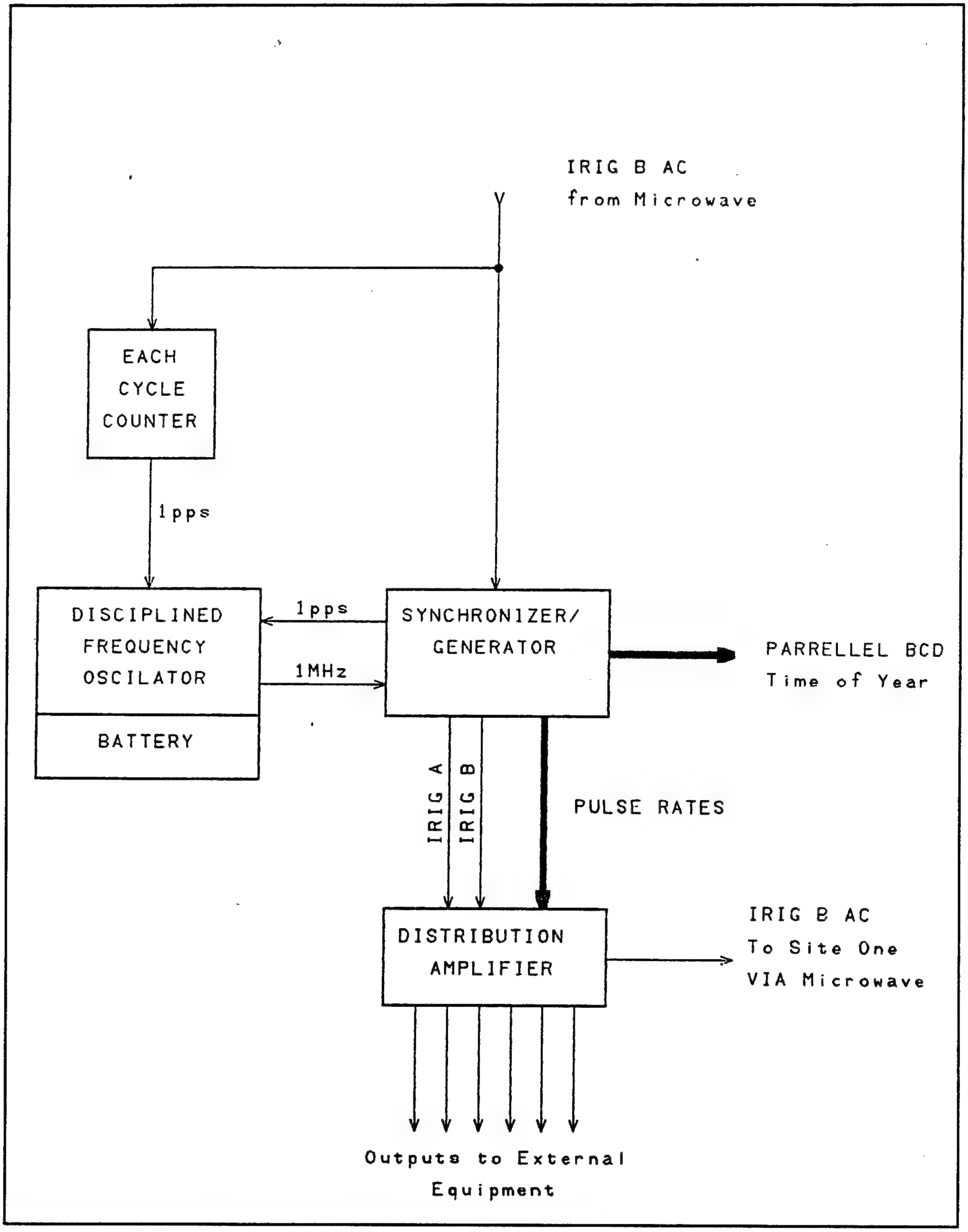



**Figure 18-2. The ASTS block diagram (typical site).**

## 5.0 SHORT -TERM PLANNED UPGRADES

Central timing is currently in the process of writing specifications for the procurement of new portable time code generators to replace the Datum model 9150 TCGs bought in 1973. The new unit will

- generate precision frequencies, pulse trains, time marks, and time codes;
- synchronize to within less than 1 microsecond relative to reference standards, internal or external;
- provide operator setup, control, and display of time and timing offsets for time codes and pulse timing relative to external sources;
- provide function indicators and alarms;
- switch automatically between ac power and battery operation during power outages and transport;
- accept external reference frequencies of 1, 5, and 10 MHz; frequency selection is automatic with provision for manual override;
- provide outputs of IRIG $A_{ac}$, IRIG $B_{ac}$, IRIG $A_{dc}$, IRIG $B_{dc}$, pps, 1 kpps, 1 ppm, 1 MHz, and pinger pulse (a specialized pulse used for driving a synchronized pinger on a vessel); and
- have battery backup of no less than 1 hour.

## 6.0 LONG-TERM PLANNED UPGRADES

Consideration is being given to procuring GPS timing receivers for each of the downrange sites. Excessive jitter at the Aydin digital microwave system output causes synchronization degradation of timing signals to and from each site clock. With individual GPS receivers providing a constant IRIG $B_{ac}$ or IRIG $A_{ac}$ output, each ASTS could be operated in the synchronous mode and maintain a higher degree of accuracy and stability.

Consideration is also being given to the establishment of a timing station at the AUTEC headquarters building in West Palm Beach, Florida. This requirement would be for support of preparing synchronous pinger assemblies for installation on vessels to be tracked by AUTEC and to provide timing information to new host computers for processing track data, simulation, and interrange and user data transfer.

## SECTION 19

## NAVAL UNDERSEA WARFARE CENTER
## DIVISION KEYPORT
## RANGE TIMING SYSTEM

### 1.0 INTRODUCTION

The range facility's mission is to provide undersea and above water tracking in support of ASW programs and related undersea research.

### 2.0 CAPABILITIES

Timing Signals:

Code format: IRIG B 1 kHz carrier, amplitude modulated
Parallel BCD: days through milliseconds.
RS 232C: bidiriectional, days through milliseconds.

Repetition Rates: 1, 10, 100, 1000, 10,000K, 100,000, 1M, 5M, 1OM pps, TTL level, 50% duty cycle, positive edge on time, driving 10 TTL loads

Primary Frequencies: 1, 2, 4 pps, TTL level, 1 millisecond duty cycle, positive edge on time, driving 10 TTL loads.

Other: Time tagging and event timing, time tag events to 10 nanosecond resolution

Time Accuracy: GPS Time ±100 ns, UTC - USNO ±150 ns
±300 ns during enforcement of selective availability

Frequency Accuracy: $\pm 1X10^{-9}$ when tracking satellites, after one day of averaging

Frequency Stability: $1X10^{-8}$ when not tracking satellites.

Availability: All range timing systems are available for use by range customers.

## 3.0. TIMING SYSTEM DESCRIPTION

The Range Timing System provides highly accurate real-time reference and frequency standards on the Northwest Range System. The Range Timing System is used at the synchronous range sites to synchronize 3-D pingers and to provide precise time correlation of range events. Selected range events are time tagged, recorded, and then used for data post processing. The system is made up of three major components:

- Global Positioning System (GPS) based Time Code Unit (TCU);
- Distribution amplifiers, cabling ;and
- Portable Timing Standards (PTS).

Timing signals used on the Northwest Range System are referenced and traceable to the United States Naval Observatory (USNO), Coordinated Universal Time (UTC) time scale as determined by the International Time Bureau.

The GPS TCU receives UTC time-of-day information referenced to the USNO via GPS satellites. The UTC time-of-day is then offset to local time by user inputs to the GPS TCU. The GPS TCU time and frequency outputs are typically synchronized to within 1 microsecond of the UTC time. The GPS TCU is capable of synchronization to USNO UTC anywhere in the world where its GPS antenna can be provided with a clear view of the sky and horizon. The GPS TCU is used at NUWC Division Keyport tracking centers and onboard NUWC Division Keyport range craft.

Io (pronounced "eye zero") is the primary frequency standard used for the synchronization of range events and 3-D tracking equipment. Io is used at two different repetition rates:

- 1 pulse per 2 seconds typically used on short baseline range sites (Nanoose and Dabob range sites), and

- 1 pulse per 4 seconds typically used on long baseline range sites (Quinault range site and temporary tracking range site applications).

Interrange Instrumentation Group B (IRIG B) is the primary time code used on the Northwest Range System for display, recording, synchronization, data logging, and backup time. More information concerning IRIG formats can be found in RCC document 200-95, IRIG Serial Time Code Formats.

Distribution amplifiers are used to distribute IRIG B, Io, and other frequency standards at the Northwest Range System Tracking Centers. Distribution amplifiers are configured on a one-to-one basis (one amplifier per load).

Portable Timing Standards (PTSs) provide another source of very accurate timing signals synchronized to UTC. The PTSs are ruggedized and designed to be used at remote locations or installations where there is limited access to power or other timing signals. There are presently three versions of the PTSs:

1. Global Positioning System (GPS) Field Portable Clock (FPC)
2. NUWC Division Keyport's Portable Timing Standard (PTS), and
3. NUWC Division Keyport's Rackmount Timing Standard (RTS).

All are capable of stand-alone battery operation and can be used for an extended period at remote sites.

The GPS Field Portable Clock (FPC) is synchronized to UTC time via the GPS satellites. Once the FPC is synchronized, it will maintain that synchronization to within 250 microseconds of UTC for a minimum of 12 hours. The FPC incorporates a disciplined quartz oscillator which is aligned with the GPS satellite Cesium Beam Oscillator Standards, thus allowing it to maintain synchronization for extended periods of time without continuous GPS satellite inputs. It can be synchronized anywhere in the world where its GPS antenna can be provided with a clear view of the sky and horizon. The FTC is capable of maintaining 8 hours of battery operation or continuous operation on ac power.

The PTS is a NUWC Division Keyport designed timing standard and incorporates a highly accurate, low drift rate rubidium oscillator as its internal frequency reference. It is synchronized by an external Io frequency standard that is referenced and traceable to USNO UTC time of day. Once synchronized, the PTS is capable of maintaining that synchronization with < 2 micoseconds of drift per day. The PTS is capable of providing 3 hours of battery operation or continuous operation on ac power.

The RTS is the rackmount version of the PTS. The internal electronics are nearly identical.

## 4.0 NEAR-TERM PLANNED UPGRADES

Upgrades to current distribution schemes include the implementation of distribution amplifiers used to amplify and to buffer timing signals.

## 5.0 LONG-TERM PLANNED UPGRADES

All timing systems are currently being upgraded to GPS time-based systems traceable to USNO UTC.

SECTION 20

# UTAH TEST AND TRAINING RANGE
# HILL AIR FORCE BASE, UTAH
# INSTRUMENTATION TIMING SYSTEM

## 1.0 INTRODUCTION

The mission of the Utah Test and Training Range (UTTR) is to test and evaluate aircraft, unmanned air vehicles (UAVs), cruise missiles, and munitions with the customers to provide customized test and training services and facilities to enhance combat readiness, superiority, and sustainability.

## 2.0 CAPABILITIES

Timing Signals:

| | |
|---|---|
| Code Format: | IRIG B, IRIG A, IRIG G, and IRIG H |
| Repetition Rates: | 5-2000 seconds |
| Primary Frequencies: | 1, 10, 100, 1000, 2400, 10,000, 100,000, 1,000,000 pps +5 microseconds |
| Other: | None |

Time accuracy: +5 microseconds
Frequency Accuracy: 5 parts is $1X10^{11}$
Frequency Stability: 5 parts in $1 X 10^{11}$ for 10-second averaging
Availability: All major sites and broadcast on VHF at 142.5 and 142.9 MHz

## 3.0 TIMING SYSTEM DESCRIPTION

The timing system at UTTR ensures a reference time of day to which all range measurements are coordinated. Different time code systems exist with many makes and models of timing equipment embedded in each system. The major time code users are radar systems, telemetry systems, range television, High Accuracy Multiple Object Tracking System (HAMOTS), HAMOTS Upgrade System (HUS), photo-optical instrumentation, Mission Control Center displays, and Air Operations Center (AOC) displays.

Range timing is established through the use of the GPS timing system. The GPS receivers are located at Wendover Field, Wendover Peak, Granite Peak, Cedar Mountain, Pad 27, and Grassy Mountain East. Two GPS receivers are located at the master timing station located in room 106, building 1274, Hill Air Force Base. Timing information is distributed to sites not equipped with GPS receivers by microwave and fiber-optic cable and broadcast timing transmitters.

The TCGs, synchronized to the timing signal, compensate for propagation delay and generate the same or different time codes. Timing is also sent to the AOC in building 1276. In the event one or more of the GPS receivers fail, timing is distributed to the appropriate sites from the master timing station by microwave and fiber optic cable.

## 4.0 PLANNED UPGRADES

The UTTR timing system has recently been upgraded through the use of GPS. There are no additional near-term or long-term planned upgrades.

SECTION 21

# WHITE SANDS MISSILE RANGE
# NEW MEXICO
# TIMING SYSTEM

## 1.0 INTRODUCTION

Established in 1945, White Sands Missile Range (WSMR) is currently the largest overland testing facility in the Department of Defense (DOD). Located in southern New Mexico, WSMR encompasses an area of approximately 4000 square miles. Range systems, which include radar, optics, and telemetry, provide support to major test facilities, laboratories, and launch complexes for all DOD agencies as well as NASA and commercial users.

To support these range systems, timing has a master clock and timing generation system, a network of distribution stations, two VHF transmission systems, and GPS timing receivers. The following paragraphs describe each of these systems and their present capabilities. The last sections discuss the short- and long-term plans for improving the overall timing system.

## 2.0 CAPABILITIES

Time Code Formats. Range instrumentation at WSMR uses standard IRIG formats to time stamp events that occur during a test. These IRIG formats are directly traceable to Coordinated Universal Time (UTC). Table 21-1 lists the IRIG formats used at WSMR.

TABLE 21-1. AVAILABLE TIMING CODE FORMATS

| Format A | Format B | Format D | Format E | Format G | Format H |
|---|---|---|---|---|---|
| A003 | B002 | D002 | E002 | G142 | H002 |
| A133 | B003 | D122 | E122 | | H122 |
| | B122 | | | | |
| | B123 | | | | |

Pulse Rates and Output Interfaces. Range instrumentation systems require a variety of output interfaces and pulse rates. Pulse rates start at 1 pulse per second and increment by a factor of 10 to 10 million pulses per second. Output interfaces include RS-232, RS-422, IEEE-488, and TTL logic signals.

Time Accuracy. When using GPS timing receivers, timing can maintain synchonization of individual customers to within 300 nanoseconds of UTC. The timing distribution and VHF transmission systems can maintain synchronization from 25 microseconds to under 5 microseconds depending on the customer's requirements.

Frequency Accuracy and Stability. Cesium Beam Frequency Standards maintain the precision of the Master Timing Generation System and provide a time base accuracy of $1X10^{-11}$ with long term stability of $5X10^{-12}$.

Availability. The IRIG time formats are available on the range 24 hours a day,
7 days a week.

## 3.0 RANGE CONFIGURATION

Three range areas make up the majority of the timing system configuration at WSMR (see figure 21-1). The south range includes all range area south of U.S. Highway 70 and Lake Lucero and encompasses the Small Missile Range. The central range extends from the northeast corner of the range at U.S. Highway 380 and the northwest corner at Rhodes Canyon to the south range line. Finally, the north range area consists of all range property north of the central range boundary including the WSMR range extension.

Master Timing Generation System. The system uses a Cesium Beam Timing Standard as its master clock. See figure 21-2 for a schematic of the Master Timing Generation System. The output of this clock feeds three redundant time code generators that produce the IRIG time codes used for distribution. This system, located at Uncle-2 in the south range, stays within 1 microsecond of UTC by using LORAN C and GPS.

VHF Transmission Stations. Timing has two VHF broadcast stations that transmit IRIG B timing. These stations are Uncle-5 in the south range and Uncle-52 in the north range. The combination of these two stations provides coverage to 95 percent of the range area and allows range users to synchronize their systems with range timing wherever wire line services are not available.

Fixed Distribution Stations. Fixed distribution stations located throughout the range receive radio timing from either Uncle-5 or Uncle-52. These stations synchronize their time code generators to radio timing and distribute time codes using wire line cable. Figure 21-1 illustrates site location and their relationship to the master station.

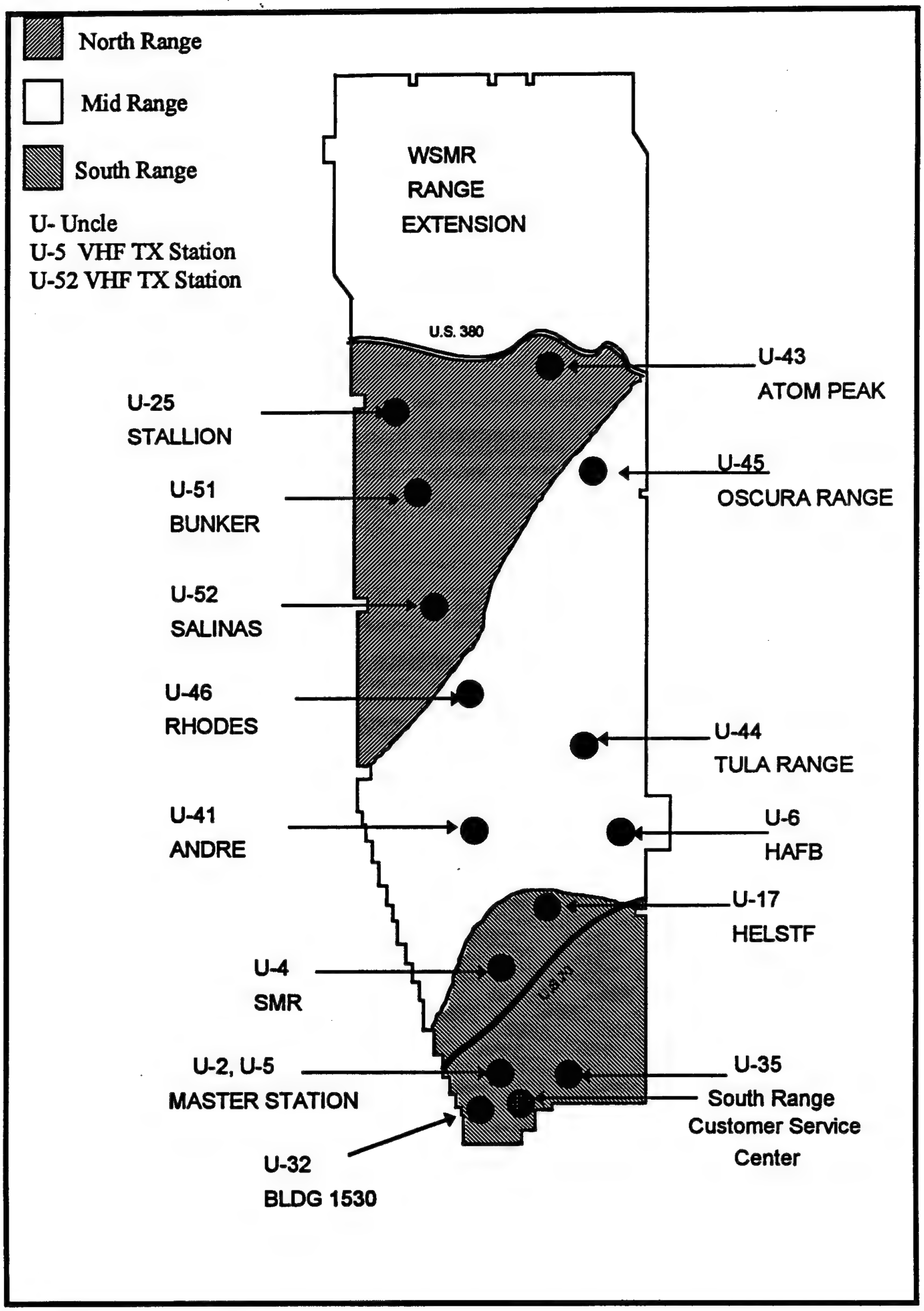



Figure 21-1. Current fixed and relay distribution system.

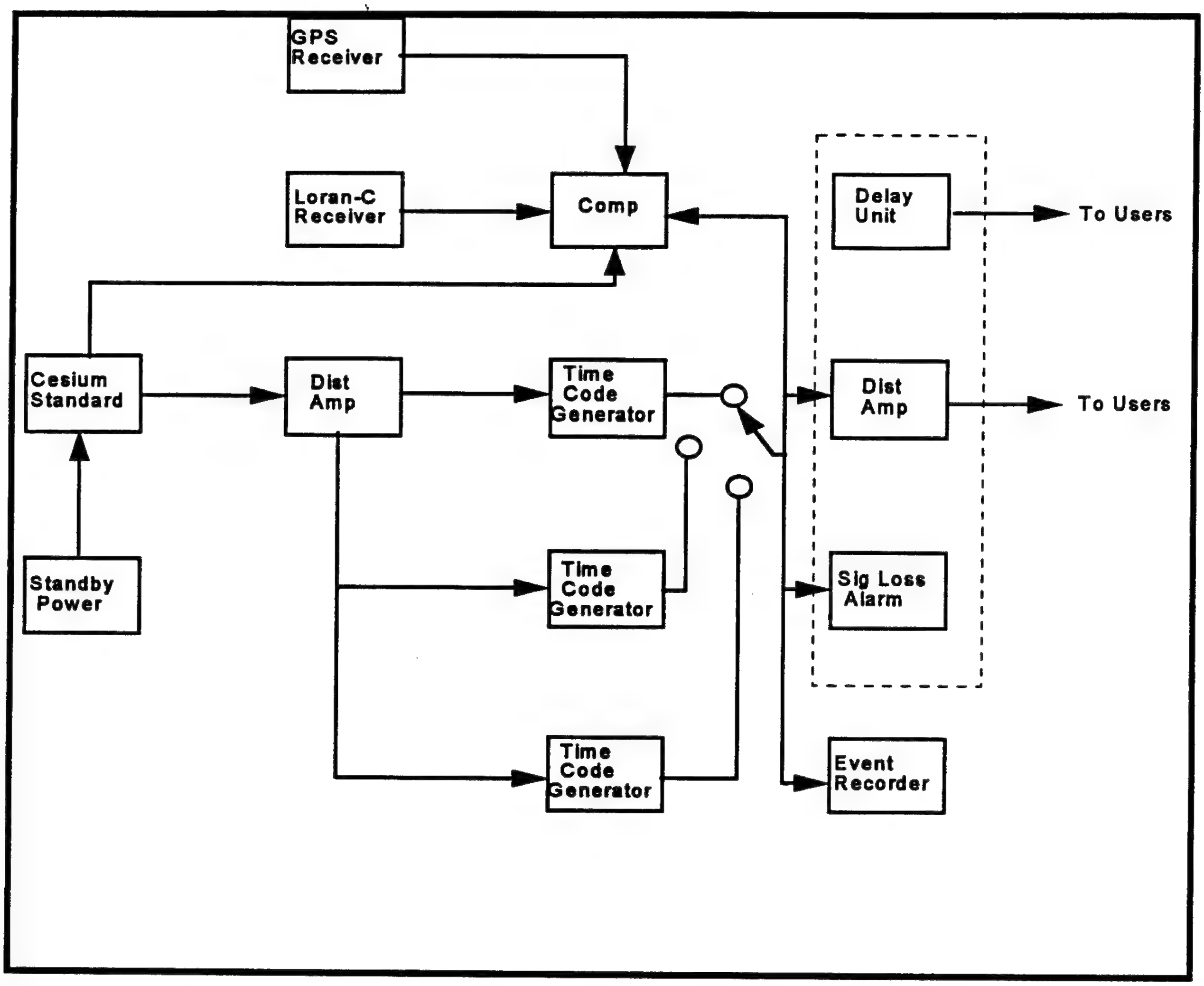



Figure 21-2. Current WSMR master timing generation system.

Mobile Distribution Stations. For areas of WSMR that do not have wire line services available from a fixed distribution station, timing provides a mobile distribution service. Currently, timing has three mobile distribution stations available for on-range support. Each system is capable of generating IRIG time code formats and receives synchronization from radio timing or GPS.

Mobile Clocks. Timing operates two transportable clock facilities for calibrating timing systems and validating GPS receivers. The transportable clock facilities consist of a mobile clock facility based in the south range and a portable clock facility based in the central range. The mobile clock facility receives synchronization from Uncle-2 and the portable clock facility from Uncle-6. A clock provides precision on-time pulses for comparison with a pulse generated at a site or location. The time difference (offset) between the pulses can be changed to a predetermined value such as zero or can be recorded as the "time bias" of that site.

Once these calibrations are complete, the clock compares its precision pulses with its synchronization source, thus verifying system operation by completing a loop closure.

Mobile Aircraft Synchronization Station. Timing operates a mobile aircraft synchronization station (Uncle-60). This station provides synchronization to aircraft for mission support. Additionally, timing equipment may be installed in aircraft by personnel who operate this station.

## 4.0 SHORT-TERM PLANNED UPGRADE

Master Timing Generation System. Figure 21-3 is a diagram of timing's design concept for a modern redundant Master Timing Generation System. The system shown uses a single GPS receiver and a set of Cesium Standards. The output from the GPS receiver initially synchronizes the time generation components and then functions as an independent reference for the Cesium Standards. The on-line standard is constantly monitored and compared with the off-line standard. If an excessive amount of phase difference develops, the system will compare both standards with the GPS and determine which standard should be on-line. By using GPS as a tool for the Timing Generation System, the system has UTC traceability and can operate independently of the GPS source. Other system features include a triple redundant time code generation configuration, error checking of all generated time codes, and automatic switching among the three generators. This system, once fully implemented, will have the capability of remaining within 100 nanoseconds of UTC and will be more efficient in maintaining this accuracy. This system is scheduled to be on-line by the end of 1996.

Relocation of the Master Timing Station. To use the available personnel more efficiently, timing is combining the master timing station with its South Range Customer Service Facility. The master timing station's new location will be at C-station. This project should be complete by the end of 1996.

Monitoring Capabilities. An important feature of the new master timing station will be its capability of monitoring remote GPS receivers. The master timing station will poll GPS receivers for status information and will alert maintenance personnel when problems arise.

VHF Transmission System. Timing has experienced GPS interruptions caused by systems on the ground. To ensure an alternative source for timing, WSMR will continue to broadcasting IRIG B. At present, timing has not planned any upgrades to this system; however, the system will continue to be monitored.

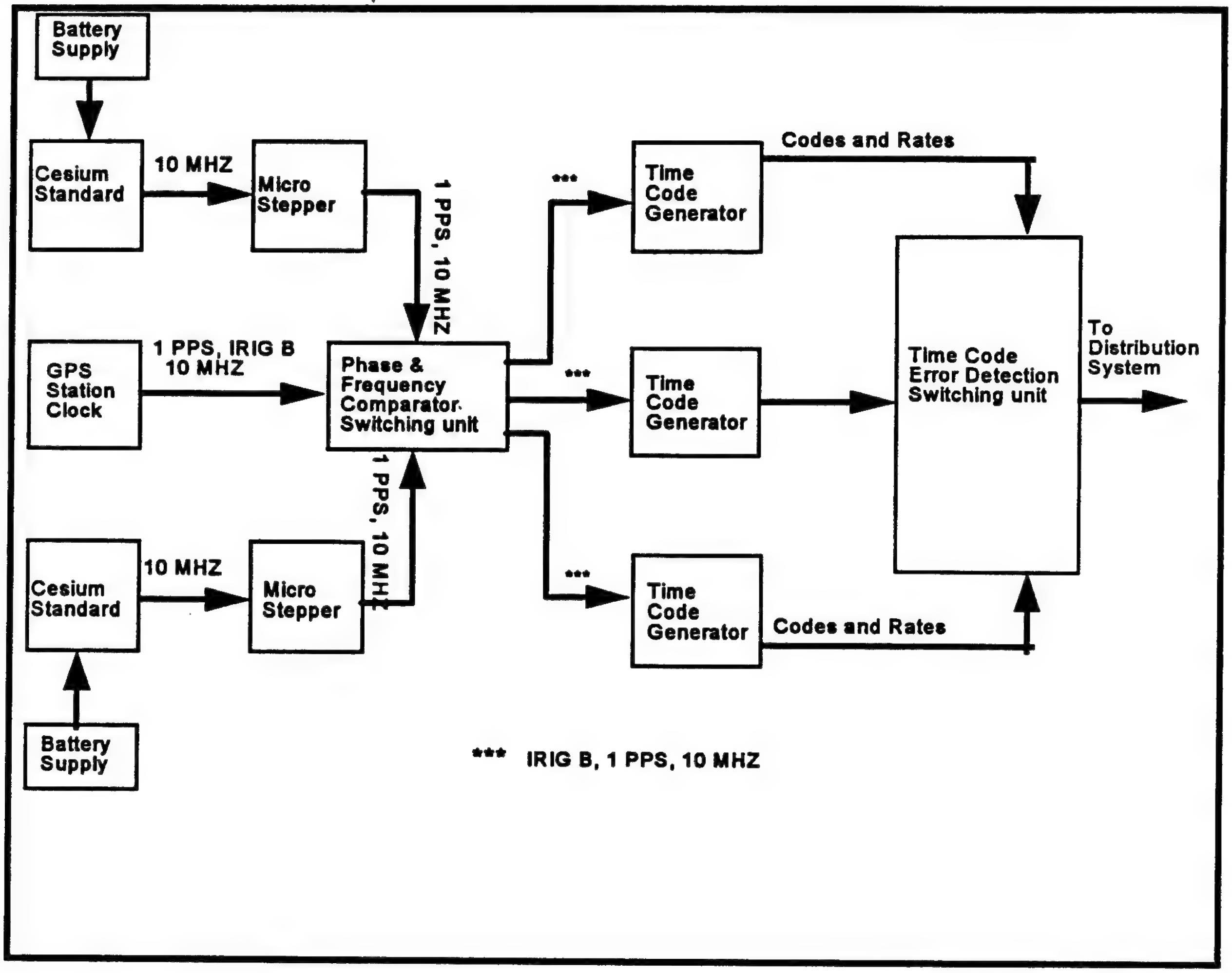



Figure 21-3. New master timing station generation concept.

Fixed Distribution Stations. By providing GPS receivers to many customers, timing can reduce the number of distribution stations required to support its functions. In fact, once timing has enough GPS receivers, it should be able to reduce the number of distribution stations to five. Two of the distribution stations, Uncle-6 and Uncle-25, will have a dual role. There will also be customer service centers responsible for maintaining, monitoring, and distributing timing equipment which should make the overall timing system more user friendly and provide quick response times to timing trouble calls. The other three distribution stations at Uncle-2, Uncle-17, and Uncle-32 will have limited distribution in locally confined areas (see figure 21-4).

Mobile Distribution. In locations where several systems will require timing but will not remain at the site for a long period of time, timing will be distributed from a local distribution van. These vans will have GPS receivers, synchronized time code generators, and all the necessary ancillary equipment.

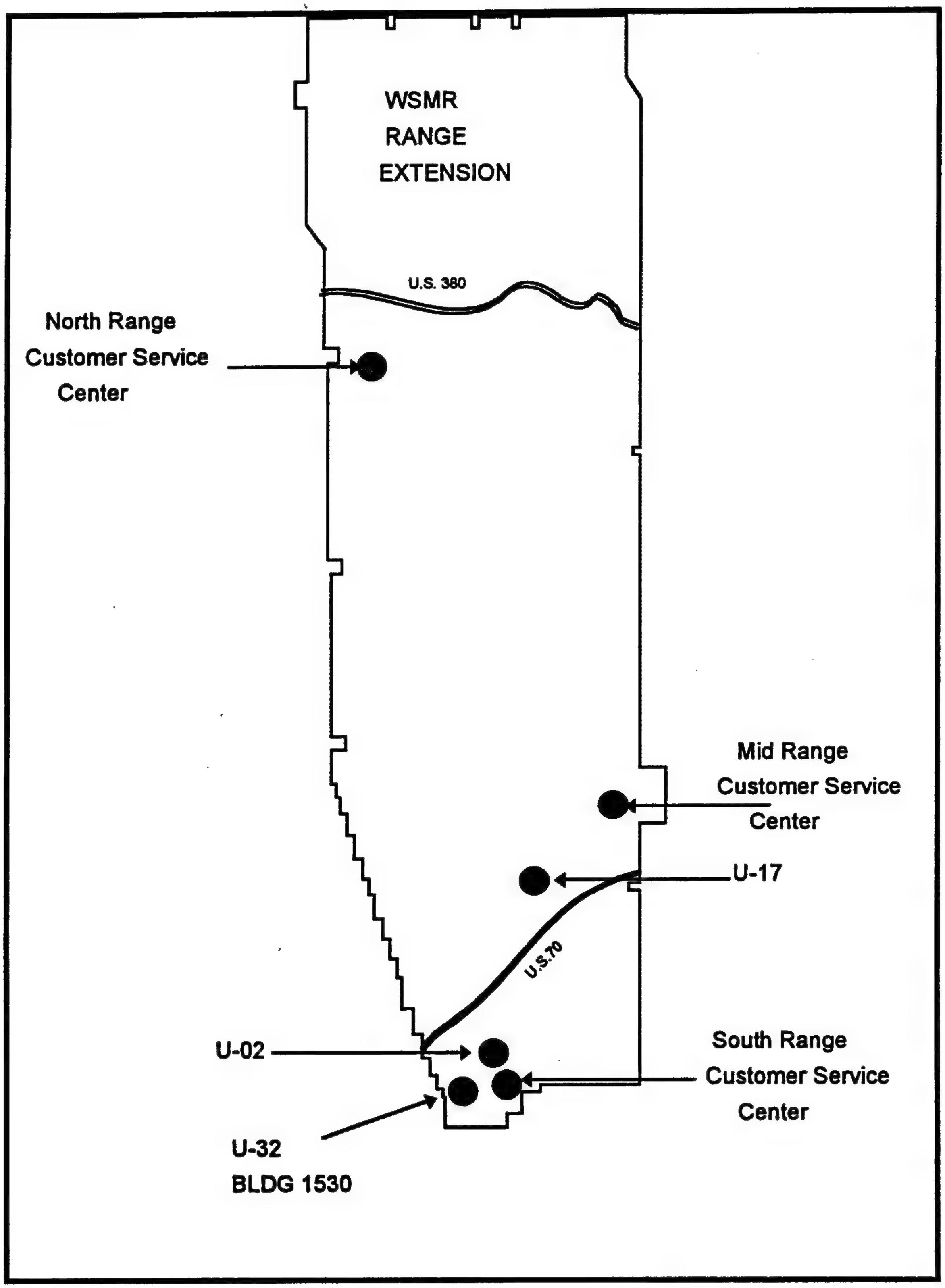



Figure 21-4. 21st century WSMR timing range support configuration.

Mobile Clocks. The WSMR mobile clocks currently have all the equipment necessary to make independent time interval measurements. Not furnished are automated data collection systems that could provide customers with hard copies of their systems performance. Timing plans to correct this deficiency by installing automated testing systems in the mobile clocks. These systems will provide performance data to the customer and have storage mechanisms to aid timing personnel in evaluating the history of timing equipment.

## 5.0 LONG TERM PLANNED UPGRADES

To continue to be an efficient and effective system in the 21st century, upgrading to GPS will be a high priority. Plans include a comprehensive monitoring system capable of evaluating remote timing systems to further improve the quality of service.

## APPENDIX A

## GPS STEERED RUBIDIUM FREQUENCY STANDARD FOR THE NASA SLR NETWORK

**GPS Steered Rubidium Frequency Standard for the NASA SLR Network**

Jeff Ingold, Richard Eichinger, Howard Donovan, Thomas Varghese
AlliedSignal Technical Services
Lanham, Maryland 20706, USA

Wayne Dewey
TrueTime, Inc.
Santa Rosa, California 95407, USA

John Degnan
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771, USA

## Abstract

The replacement of the high performance cesium beam tubes in the NASA Satellite Laser Ranging (SLR) Network as well as the automation of the current time and frequency systems are prohibitively expensive. This paper describes an alternative approach towards achieving high precision and automation of the time and frequency systems by using a Global Positioning System (GPS) time and position receiver to steer a rubidium oscillator. The steering is accomplished by using a frequency correction loop to control the C-field of a rubidium oscillator. After a 24 hour acquisition period, the maximum incremental frequency change is constrained to 6 E-14 in no less than one minute intervals. Time and frequency from the steered rubidium provide acurate frequency reference signals and time synchronization for the telescope and transmit/receive electronics. Accurate time reference to the US Naval Observatory for precise laser epoch measurement is also provided. Results from laboratory and field tests will be presented.

## Introduction

Cesium beam frequency standards have been the cornerstone of the NASA SLR time and frequency systems for the past eighteen years. Within the past eight years, all of the original cesium beam frequency standards have been refurbished with updated electronics and new cesium beam tubes. The current price for a high performance cesium beam tube is US $25,000. Many of these standards will require a replacement cesium beam tube in the next few years. A viable alternative to cesium standards is to use a low cost multi-channel GPS receiver to slowly steer a rubidium oscillator.

## Background

Two methodologies for frequency control used by many manufacturers of GPS disciplined rubidiums are: 1) continuous correction, and 2) single correction every 24 hours. [1,2] Continuous correction via a twelve bit digital to analog converter (DAC) causes an abrupt frequency change of 1 E-12, impacting short term frequency stability and possibly reducing satellite laser ranging accuracy. Single corrections once every 24 hours allows a frequency offset to accumulate for 86,400 seconds, then executes a large frequency step. If this correction occurs during satellite laser ranging, data could be compromised.

Most commercial manufacturers are targeting the much larger telecommunications industry and do not address the impact these methods have on short term stability over any epoch. The main objective of our steering process is to combine the relatively good aging characteristics of the rubidium oscillator with fine frequency adjustments of 6 E-14 continuously without degrading short term stability.

## GPS Selective/Availability and SatHop

The Global Positioning System is the standard used to steer the rubidium oscillator. Many references to the operation and use of GPS can be found in published literature. [3,4] Time transfer via GPS to the United States Naval Observatory (USNO) with Selective/Availability (S/A) enabled has been observed to be +/- 300 nanoseconds using single channel receivers. (S/A is the intentional degradation of accuracy for commercial applications.) To reduce the effects of S/A on frequency steering processes, TrueTime developed the Satellite Hopping (SatHop) algorithm. [5]

Once a three dimension position determination has been successfully completed, the antenna's coordinates are retained in non-volatile memory and the receiver considers all range errors to be clock biases only. If the GPS antenna is moved, a new position must be determined.

The next step of the SatHop algorithm is comprised of two components, a satellite sequencer and a solution averager. The sequencer scans the list of satellites in view and selects one satellite for the GPS receiver to use for a timing solution (user deselected and unhealthy satellites are ignored). Because the GPS receiver is capable of tracking up to seven satellites simultaneously, virtually all visible satellites are on the list. After a dwell period of 30 seconds which generates 30 samples for the selected satellite, the next satellite in the sequence is selected. The sequencer continuously loops through the satellite list and is updated by the GPS receiver as satellites rise and set.

The solution averager creates a composite satellite clock bias solution by averaging the phase solution from all of the tracked satellites into a single 400 sample average. The decorrelation time of GPS has been determined to be 400 seconds. [6] After ten sample averages from the SatHop solution averager have occurred, a frequency error is calculated and an adjustment control word is stored in a register. The control word is divided into segments representing one binary bit of the 16 bit DAC. The segments are queued and executed on a 60 second timer, one at a time. The output of the DAC then adjusts the magnetic field (C-field) of the rubidium. One DAC bit is equal to 6 E-14 of frequency change and is an order of magnitude below the noise floor of the rubidium oscillator.

**System Hardware**

The oscillator being steered is an FRK-H-LN rubidium oscillator manufactured by Ball Corporation, Efratom Division. The oscillator has a 0 to 5 volt electrical tuning input that controls the C-field. The frequency can be controlled +/-1 E-9 via this input. Option H refers to an improved aging rate of 1 E-11/month. The LN option improves the short term stability and lowers the single side band phase noise. The frequency change due to temperature is 1 E-10 from -25 degrees C to +65 degrees C. [7]

The GPS receiver front end is a Tans Timing Module (TTM), manufactured by Trimble navigation. The remaining portion of the receiver is a TrueTime GPS-DC-MKIII. The receiver uses the steered rubidium oscillator as its timebase to synthesize the local oscillator to acquire and track the GPS satellites. Clock bias in meters is reported from the TTM and is directly converted to seconds using the speed of light in free space (3.335640952 E-9 seconds/meter) as the conversion factor. Clock bias contains the rubidium oscillator error, selective availability, variations in the GPS signal path, and system noise. [5]

The rubidium oscillator and associated RF electronics use a single linear power supply with board level DC filtering and voltage regulators for low noise and RF isolation. An external DC input is supplied for continuous operation during power outages of up to eight hours. The 10 MHz sinewave signal from the rubidium oscillator is distributed by low noise, 90 dB isolation amplifiers to drive the GPS receiver, one pulse per second (1PPS) generator, low noise 10 MHz to 5 MHz frequency divider and user output. The 5 MHz sinewave signal from the divider is distributed to four user outputs by low noise, 90 dB isolation amplifiers. These RF techniques are required to achieve minimum overall system phase noise and short term stability.

Two isolated 1PPS user outputs are generated from the 10 Mhz for phase coherency and are synchronized to the GPS 1 PPS after the 24 hour acquisition period. This technique maintains the epoch to USNO within +/-500 nanoseconds, thereby eliminating human intervention to make time steps or time bias corrections.

A user RS-232 port is available for Time of Day time-stamp as well as monitor and control.

IRIG-B modulated time code is also available to the user.

Figure 1 shows the block diagram of the GPS steered rubidium.

**Short Term Stability**

One of the major design goals of this project was to produce a system with good frequency stability at taus (sampling times) of 20 milliseconds to 50 milliseconds. These taus are the roundtrip time of flight of the laser pulse for most of the satellites tracked by the NASA SLR. These short taus are outside the normal scope of time domain metrology. [8] Frequency domain phase noise measurements were performed from 0.01 Hz to 2 MHz from the carrier using a Hewlett/Packard 3048A phase noise analyzer. The results were normalized from single sideband to double sideband, then converted to the time domain using the US National Institute of Standards and Technology (NIST) approved power-law spectra equations. [9] Use of this metrology proved useful during the development and testing cycle, as near real time results were available while the GPS receiver was correcting the rubidium. Measurements indicated no appreciable difference in phase noise or short term stability between corrected and uncorrected rubidium operation. Figure 2 is a comparison of short term stability of various 5 MHz oscillators.

**Laboratory Tests Results**

The Time and Frequency Office at AlliedSignal Technical Services in Columbia, Maryland, USA, maintains a time base traceable to USNO within +/- 50 nanoseconds via TV line 10 for the NASA Goddard Space Flight Center. From a group of several cesium beam frequency standards, the best performing unit is used as the "House Standard". The House Standard is compared to the USNO via TV line 10 in common view mode five days a week. All standards are compared to the House Standard daily. Three single channel GPS receivers are also monitored daily as depicted in figure 3. Any 5 MHz frequency oscillator can be evaluated using this system.

# GPS Steered Rubidium I

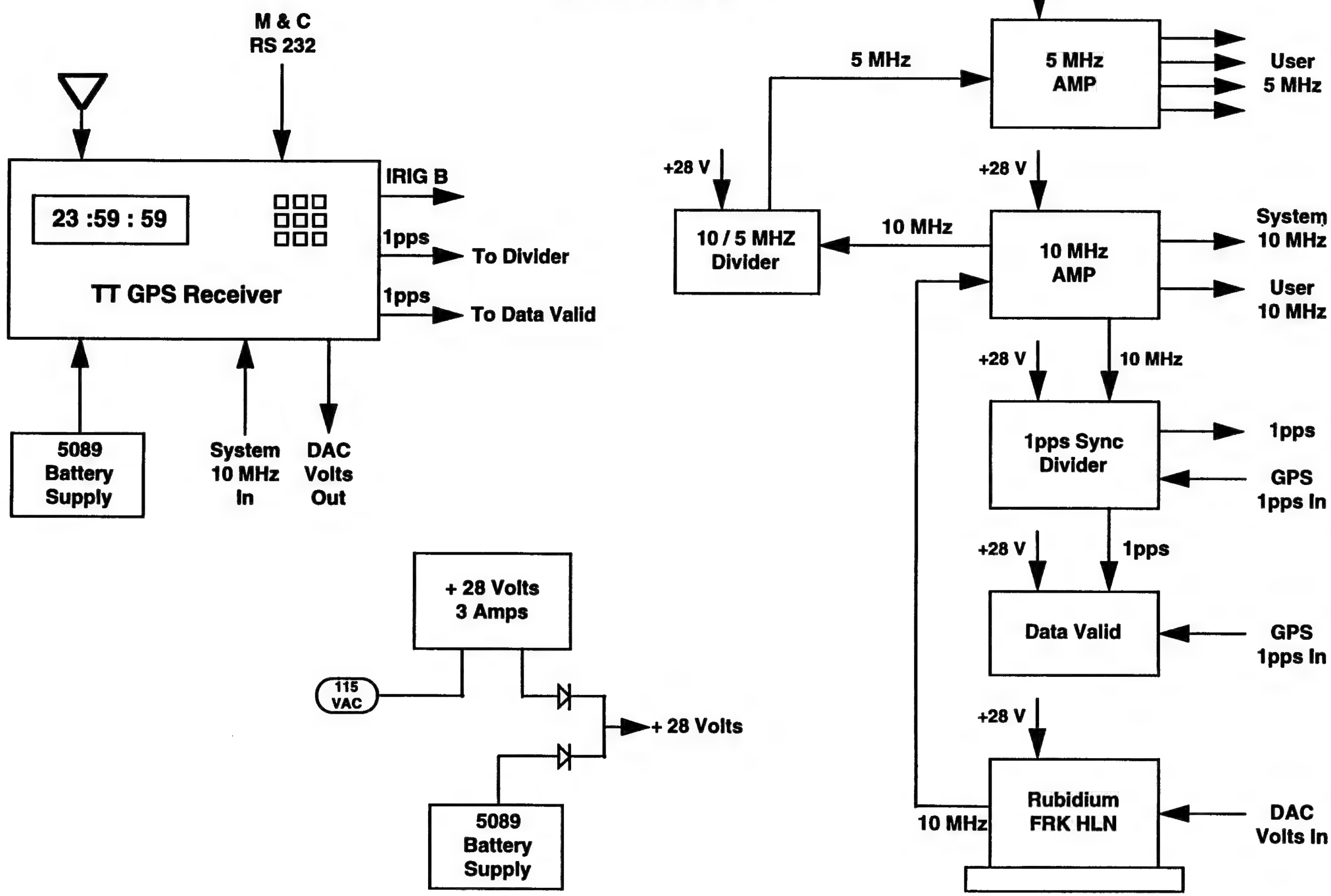



FIGURE 1

## SHORT TERM STABILITY

| TAU (sec.) | ATSC/TT | ONCE/DAY | 857 FTS | 5061A 004 | 5061B 004 |
|---|---|---|---|---|---|
| .02 | 80.4 | 409.0 | 107.0 | 81.4 | 92.4 |
| .05 | 32.3 | 165.0 | 43.0 | 33.2 | 36.9 |
| .10 | 17.0 | 83.4 | 21.0 | 17.0 | 18.5 |
| .20 | 11.0 | 42.6 | 12.0 | 9.4 | 9.5 |
| .50 | 6.5 | 17.6 | 9.4 | 5.7 | 5.0 |
| 1.0 | 4.2 | 9.5 | 9.9 | 4.2 | 4.4 |
| 2.0 | 3.0 | 5.3 | 9.7 | 3.9 | 4.2 |
| 5.0 | 2.1 | 2.8 | 8.0 | 4.1 | 3.6 |
| 10 | 1.4 | 2.0 | 5.6 | 4.0 | 2.7 |
| 20 | 1.3 | 1.7 | 3.8 | 3.6 | 1.9 |

**SIGMA Y TAU IN E-12**

FIGURE 2

# GPS Steered Rubidium Laboratory Test Facility

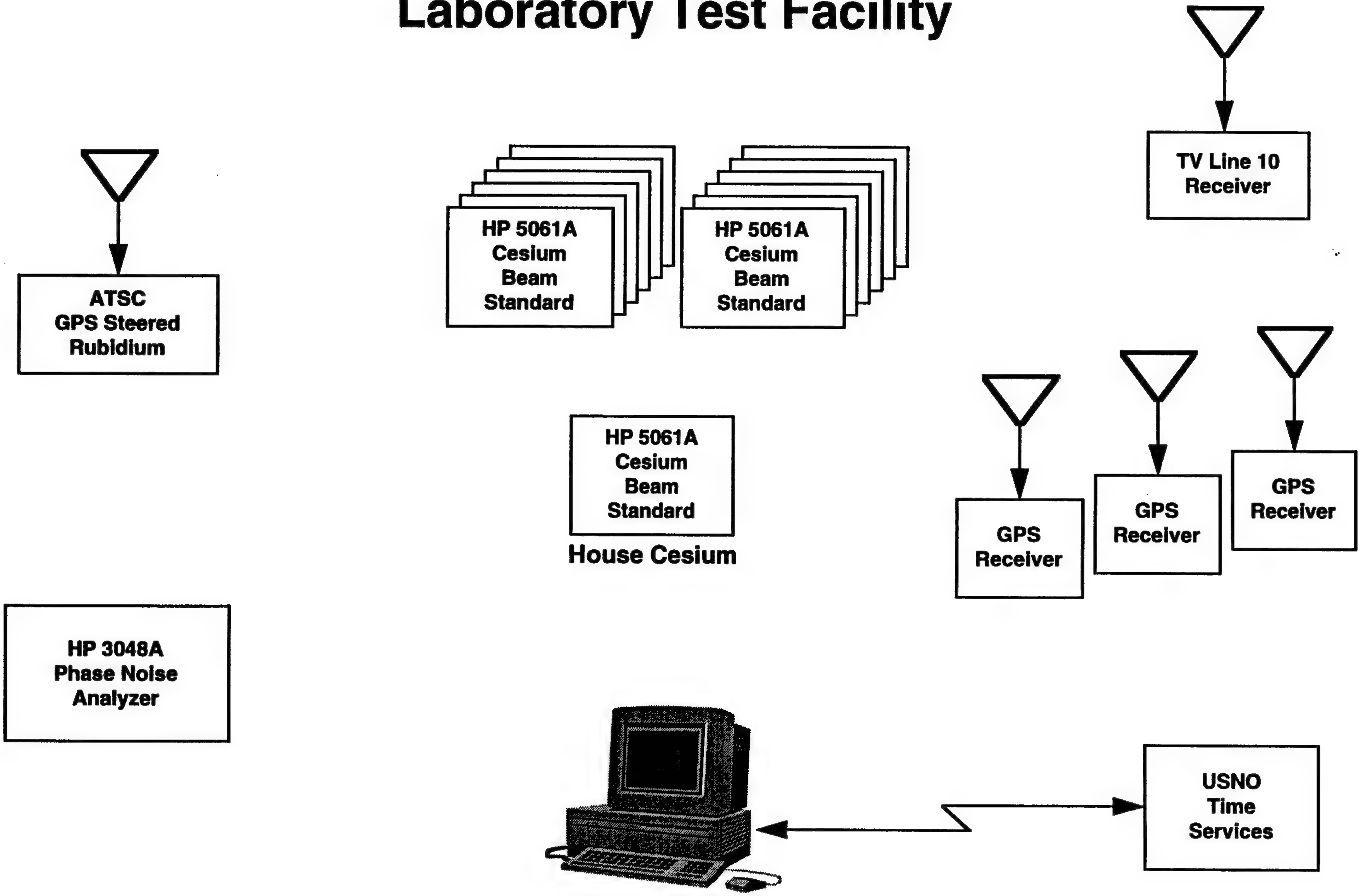



FIGURE 8

The GPS Steered Rubidium was compared to the House Standard at ten minute intervals for seventeen consecutive days from July 26, 1994, to August 12, 1994.

The 24 hour acquisition period of the GPS Steered Oscillator is obvious at the beginning of figure 4. The three small breaks in the data are from short power interruptions in the monitoring equipment. The worst case peak to peak frequency change after the 24 hour acquisition period is less than 2 E-12 over several hours. The worst case epoch error was less than 500 nanoseconds.

**Field Tests Results**

Mobile Laser System (MOBLAS) 7 located at Goddard Space Flight Center, was the field test site for the GPS steered rubidium. Figure 5 depicts the interconnections between MOBLAS 7 and the GPS steered rubidium. TV line 10 is used to measure the cesium beam frequency standard to USNO in common view mode. The Time and Frequency Office in Columbia, initiates and analyzes the measurements between USNO and MOBLAS 7. Any 5 MHz oscillator can be measured to MOBLAS 7 and traced to USNO using this method. A linear phase recorder and a single channel GPS receiver were also used to evaluate and analyze the performance of the GPS steered rubidium.

Long term frequency stability data is shown in figure 6. The data indicates that the GPS steered rubidium maintains epoch to +/- 500 nanoseconds to USNO. The maximum frequency change is less than 2 E-12 over several hours.

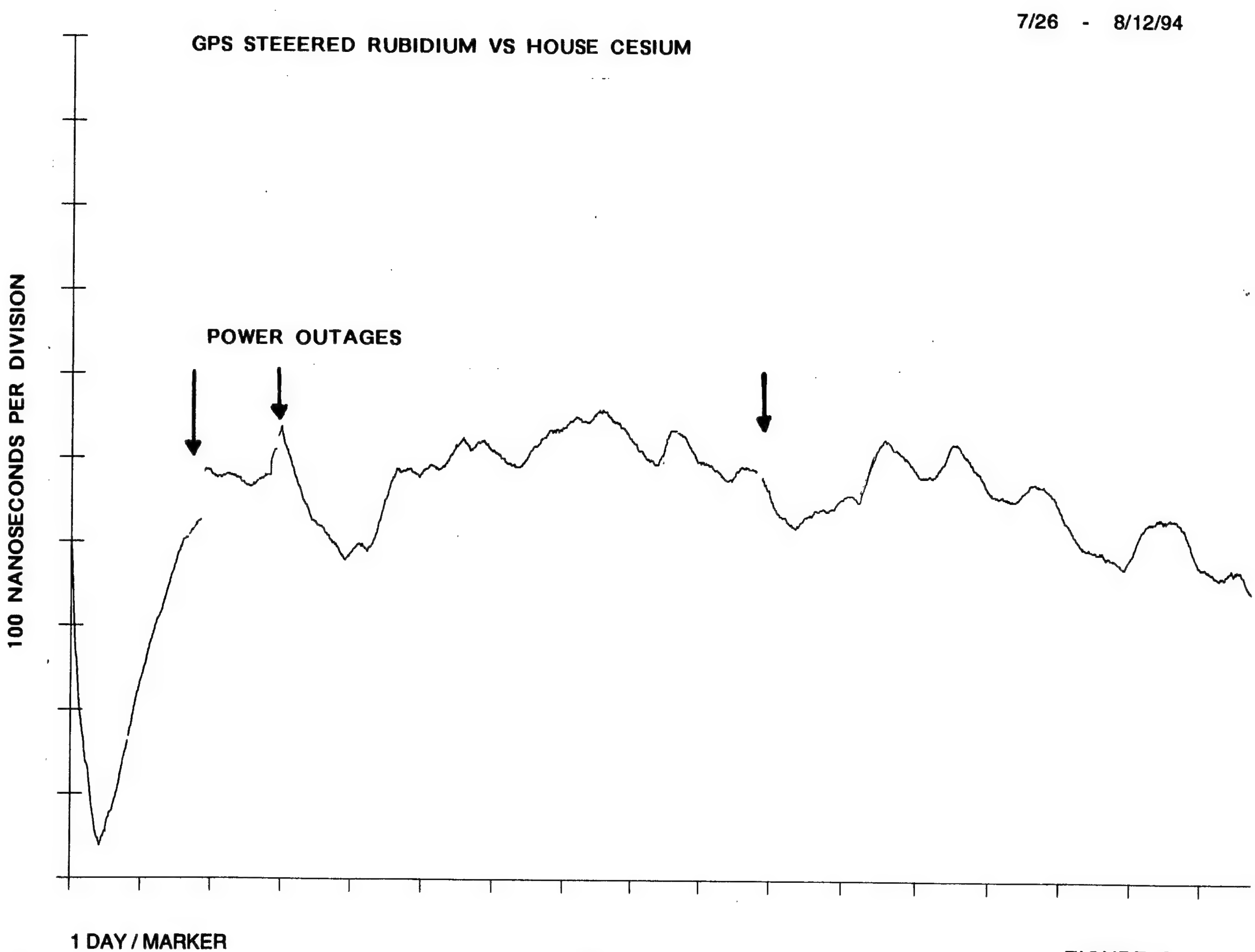
Figure 7 is SLR data taken at MOBLAS 7 on July 12, 1994. The MOBLAS 7 timebase for this Lageos-2 pass started with the cesium frequency standard. As scheduled, the GPS steered rubidium was substituted for the cesium halfway through the pass. The residuals indicate that replacing the cesium standard with the GPS steered rubidium did not impact NASA SLR data.

**Summary**

The data and techniques presented above indicate that it is feasible to replace cesium beam frequency standards in the NASA SLR network with GPS steered rubidiums.

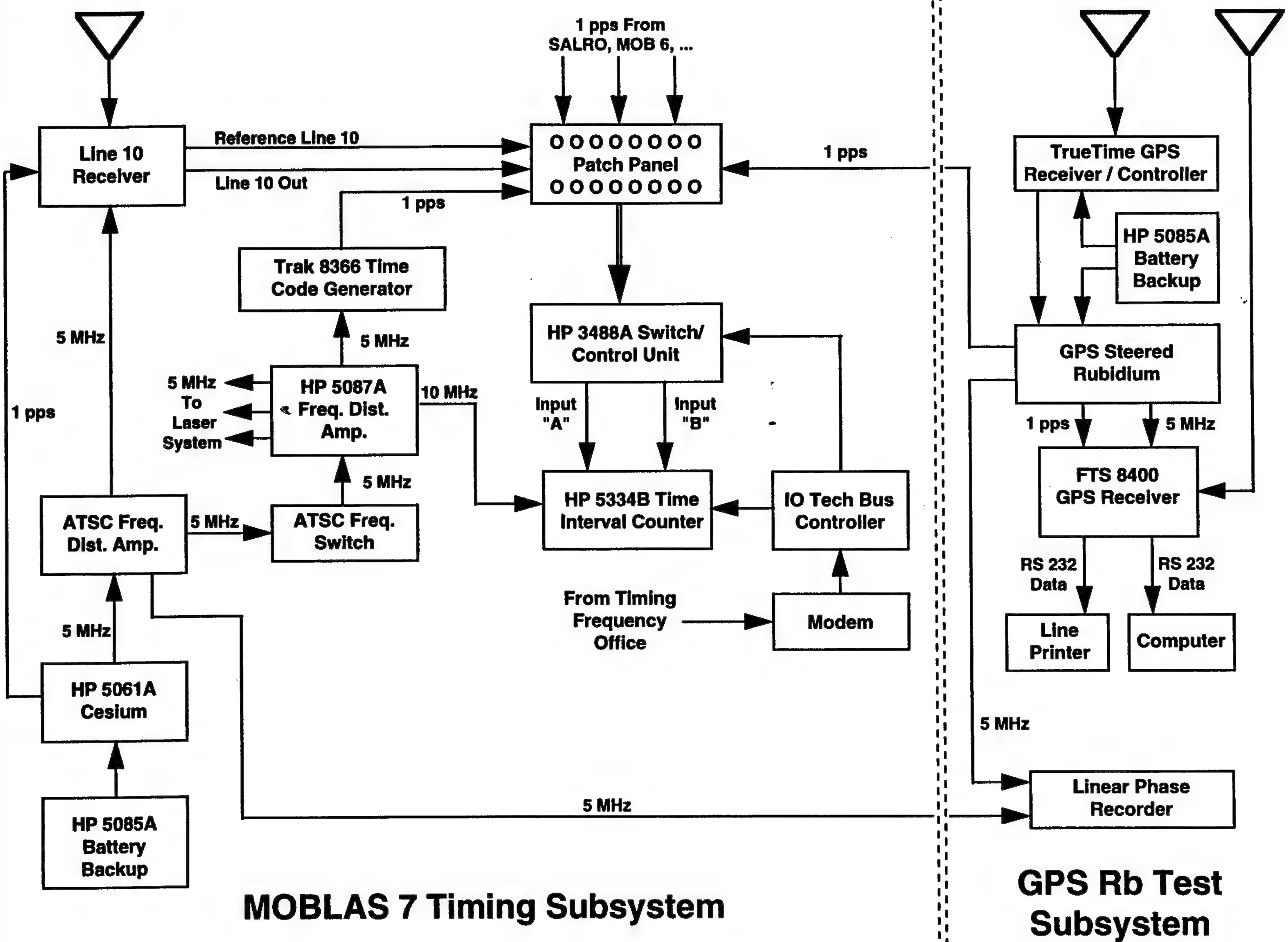
**Acknowledgment**

The authors are grateful to John Arnold, Bea Belovarich, Paul Kushmeider, Robert Price, and Harry Sadler, AlliedSignal Technical Services for the data analysis used in this paper.



7/26 - 8/12/94
GPS STEEERED RUBIDIUM VS HOUSE CESIUM
POWER OUTAGES
100 NANOSECONDS PER DIVISION
1 DAY / MARKER


FIGURE 4



1 pps From
SALRO, MOB 6, ...
Line 10
Receiver
Reference Line 10
Line 10 Out
1 pps
Patch Panel
1 pps
TrueTime GPS
Receiver / Controller
HP 5085A
Battery
Backup
Trak 8366 Time
Code Generator
5 MHz
5 MHz
HP 3488A Switch/
Control Unit
GPS Steered
Rubidium
1 pps
5 MHz
5 MHz
To
Laser
System
HP 5087A
Freq. Dist.
Amp.
10 MHz
Input
"A"
Input
"B"
1 pps
5 MHz
FTS 8400
GPS Receiver
5 MHz
HP 5334B Time
Interval Counter
IO Tech Bus
Controller
ATSC Freq.
Dist. Amp.
5 MHz
ATSC Freq.
Switch
RS 232
Data
RS 232
Data
From Timing
Frequency
Office
Modem
5 MHz
Line
Printer
Computer
HP 5061A
Cesium
5 MHz
5 MHz
Linear Phase
Recorder
HP 5085A
Battery
Backup
MOBLAS 7 Timing Subsystem
GPS Rb Test
Subsystem


FIGURE 5

10/17 - 10/28/94

GPS Steered Rubidium vs MOBLAS 7 Cesium

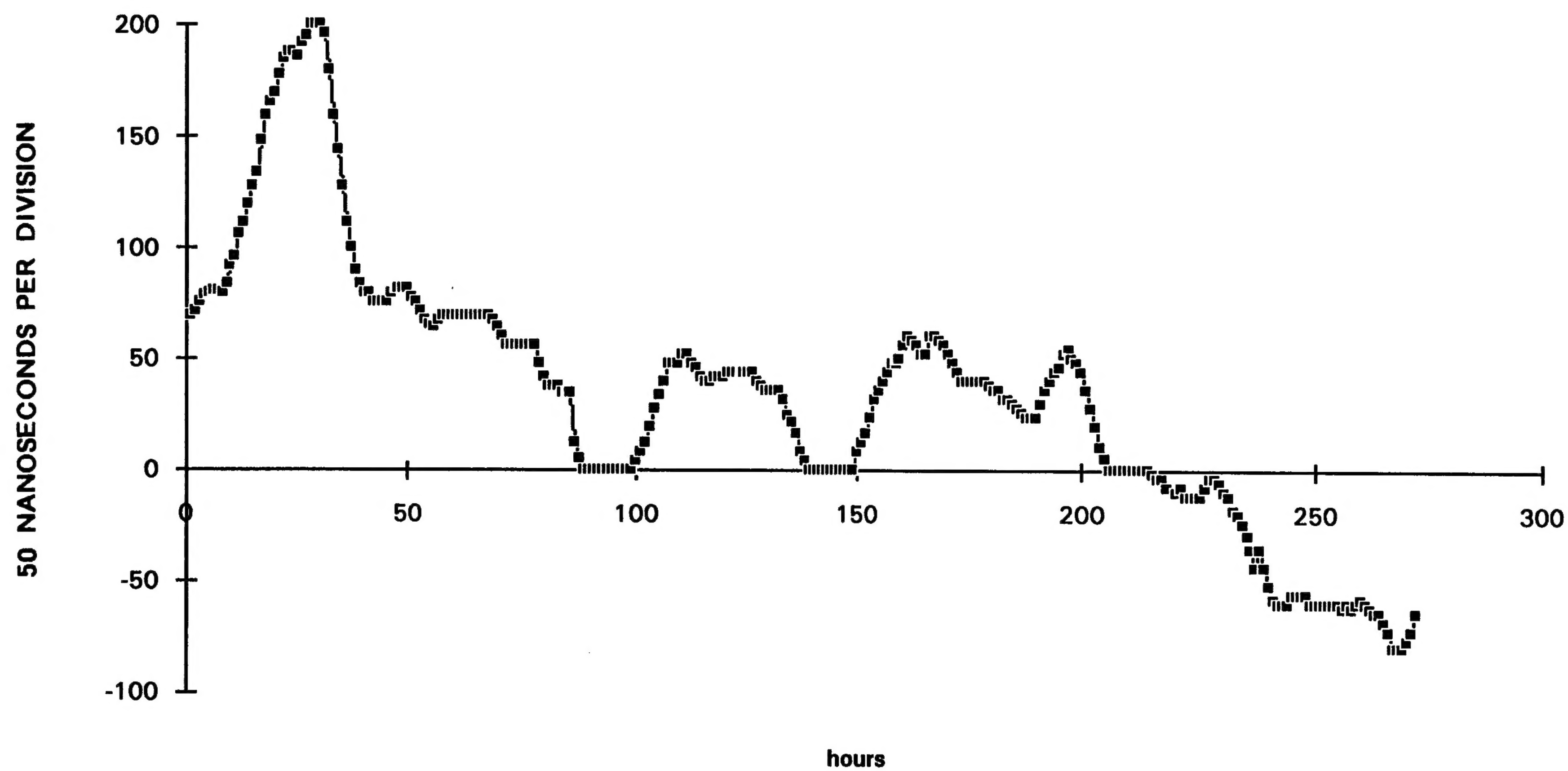



FIGURE 6

## LAGEOS-2, [illegible]y 12, 1994, 1:03Z

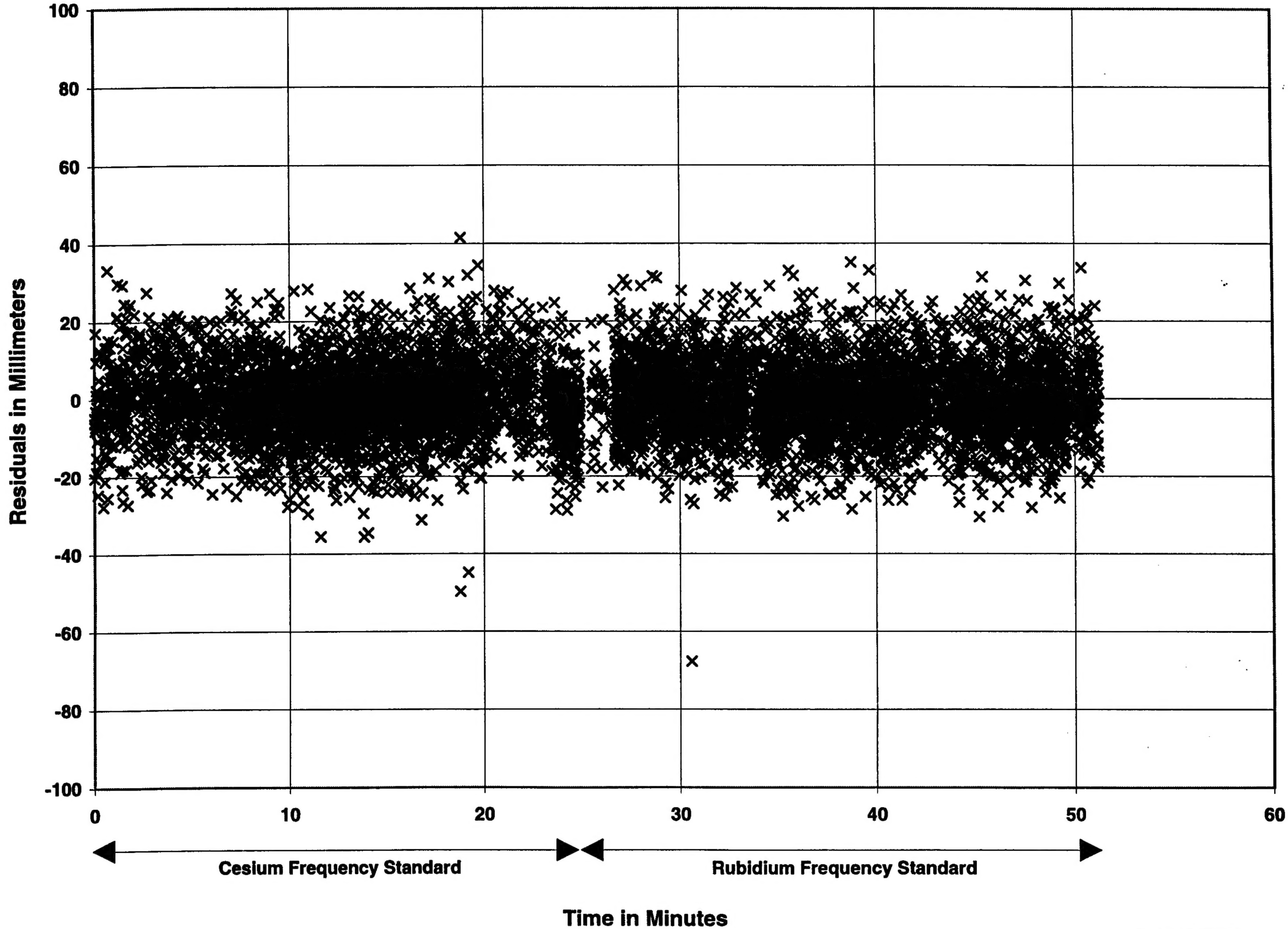



FIGURE 7

GPS STEERED RUBIDIUM FREQUENCY STANDARD

MODEL 9515

| | |
|---|---|
| GPS Receiver | C/A code, L1 carrier<br>6-channel, Parallel tracking |
| Frequency Accuracy | +/- 2.5 E-12 22 degrees C to 28 degrees C |
| Time Accuracy | +/- 500 nanoseconds to USNO<br>Coherent to 10 MHz |
| Frequency Outputs | 10 MHZ +10 dBm, 1 each<br>5 MHz +10 dBm, 4 each |
| Isolation output to output | 5 MHz, 90 dB |
| Spurious | -100 dBc |

Short term stability

| Tau (sec) | Sigma y tau |
|---|---|
| .05 | 4 E-11 |
| .10 | 2 E-11 |
| .50 | 7 E-12 |
| 1.0 | 5 E-12 |
| 10 | 5 E-12 |

Phase Noise

| Offset from Carrier (Hz) | SSB Phase Noise (dBc) 5 MHz | 10MHz |
|---|---|---|
| .1 | -70 | -65 |
| 1 | -90 | -85 |
| 10 | -120 | -115 |
| 100 | -145 | -140 |
| 1K | -150 | -150 |
| 10K | -150 | -150 |

| | |
|---|---|
| Time Code Output | IRIG B modulated, 1 each |
| Power | AC 120 volts 50-66 Hz 2.5 amps<br>DC +24 to +32 volts 2 amps |
| Maximum frequency step after 24 hours operation | 6 E-14 60 seconds or longer |
| Monitor and Control | RS-232 |
| Size | 19" x 5.25" x 19" deep |
| Weight | less than 40 pounds |

**References Cited**


1. McNabb, Jack "A Precise GPS-Based Time and Frequency System" Proceedings of the 24th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting December 1992.

2. Dewey, Wayne "A GPS Disciplined Rubidium Clock" Proceedings of the 21st Annual Precise Time and Time Interval (PTTI) Apllications and Planning Meeting November 1989.

3. The Institute of Navigation, "The Global Positioning System" Volumes I and II.

4. Ingold, Jeff et al.,"An International Time Transfer Experiment" Proceedings of the 37th Annual Frequency Control Symposium June 1983.

5. Dewey, Wayne "Disciplined Rubidium Oscillator With GPS Selective Availability" Proceedings of the 24th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting December 1992.

6. Allan, Dave, and Dewey, Wayne, "Time-Domain Spectrum of GPS SA" Proceedings of the 1993 Institute of Navigation 1993.

7. Precise Time and Frequency Handbook, Ball Efratom Division, Eighth Edition, 1991.

8. Detoma, Edoardo "Translation of Frequency Stability Measurements from the Frequency Domain to the Time Domain" AlliedSignal (formerly Bendix Field Engineering) Internal Report October 1987.

9. Temple, Robert "HP 3048A Option 301 Phase Noise Measurement System" Reference Manual Volume I.


**Additional References**


1. Goldman, Stanley "Phase Noise Analysis in Radar Systems" Wiley and Sons 1989.

2. Jespersen, Jim "Introduction to the Time Domain Characterization of Frequency Standards" Tutorials from the Twenty-third Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting December 1991.